PB84-107895

Report of the Groundwater Investigation
Lakewood, Washington
October 1981 - February 1983

(U.S.) Environmental Protection Agency
Seattle, WA. Region X

Feb 83

U.S. Department of Commerce
National Technical Information Service
NTIS

50272-101

REPORT DOCUMENTATION PAGE

1. REPORT NO. EPA 910/9-83-109

2.

3. Recipient's Accession No. PB84 107895

4. Title and Subtitle
Report of the Groundwater Investigation
Lakewood, Washington October 1981 - February 1983

5. Report Date February 1983

6.

7. Author(s) Fred Wolf and Kwasi Boateng

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
U. S. Environmental Protection Agency
Region 10
1200 Sixth Avenue
Seattle, Washington 98101

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C)
(G)

12. Sponsoring Organization Name and Address
same as above

13. Type of Report & Period Covered Oct. 1981 - Feb. 1983

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

In 1981, sampling by the Environmental Protection Agency confirmed that Lakewood Water District Production Wells H-1 and H-2 were contaminated with chlorinated hydrocarbons. Further testing revealed that the semi-confined aquifer from which the production wells are drawn was contaminated with the target compounds. The installation of deep monitoring wells indicated that the shallow aquifer was not the source of contamination. The source was subsequently identified as a discharge to a septic tank drain field at a laundry and dry cleaners. It was recommended that contamination from the identified source be eliminated, and that the production wells be pumped and sampled at intervals to make sure that acceptable levels of water purity are maintained.

17. Document Analysis a. Descriptors
Wells
Drinking Water
Ground Water
Water Analysis

b. Identifiers/Open-Ended Terms
Lakewood, Washington

c. COSATI Field/Group

18. Availability Statement: unlimited

19. Security Class (This Report) unclassified

20. Security Class (This Page) unclassified

21. No. of Pages

22. Price

(See ANSI-Z39.18) See Instructions on Reverse

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

PB84-107895

United States
Environmental Protection
Agency

Region 10
1200 Sixth Avenue
Seattle WA 98101

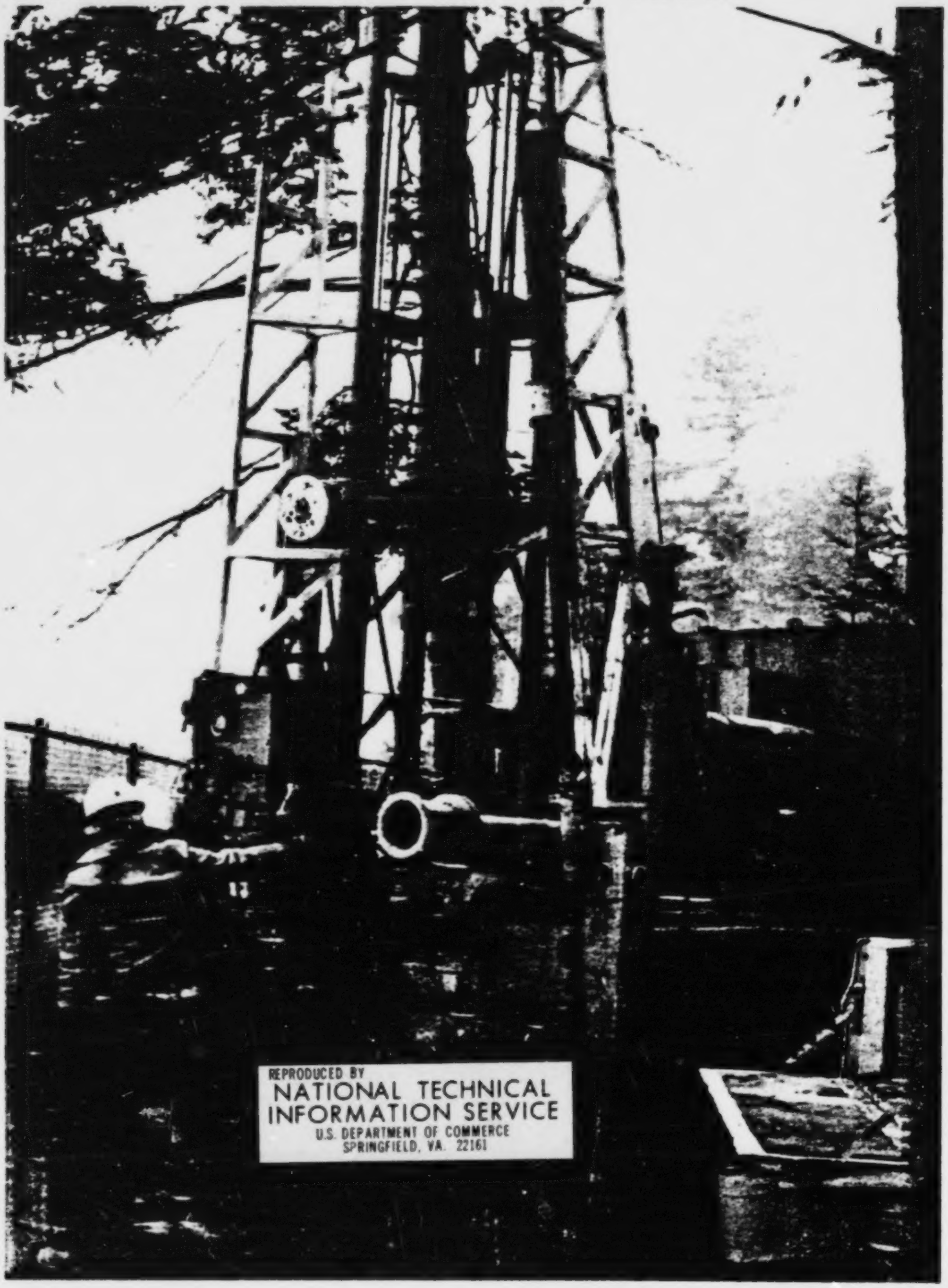
EPA 910/9-83-109

Environmental Services Division

February 1983

Report of the Groundwater Investigation

Lakewood, Washington
October 1981 to February 1983



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REPORT OF THE GROUNDWATER INVESTIGATION

LAKEWOOD WASHINGTON

OCTOBER 1981 - FEBRUARY 1983

Fred Wolf
Kwasi Boateng

U.S. ENVIRONMENTAL PROTECTION AGENCY, 1200 SIXTH AVENUE
SEATTLE, WASHINGTON, 98101

MARCH 1983

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ACKNOWLEDGEMENTS

The authors are indebted to numerous EPA, Ecology and Environment and local officials for helping to secure access to the drilling sites, providing technical support, and reviewing the draft report.

Jack Sceva of EPA and Hussein Aldis of Ecology and Environment, were instrumental in the development of the study plan and in editing the report. Their suggestions were very helpful.

We are grateful to Captain Lindsey Waterhouse and the staff of the Environmental Engineering Department at McChord Airforce Base for the use of their laboratory as our field operational base.

Special appreciation is extended to Wayne Dunbar, Bob Foster, and the entire staff of the Lakewood Water District for their high degree of cooperation and understanding.

Technical support was provided by Thomas Tobin, Stephen Testa, Jim Farr, Pete Evers and the entire staff of Ecology and Environment's office in Seattle. Jane Gans typed the report. We wish to express our appreciation to all of them.

Fred Wolf

Kwasi Boateng

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I. EXECUTIVE SUMMARY

In 1981 sampling by the Environmental Protection Agency confirmed that Lakewood Water District Production Wells H-1 and H-2 were contaminated with trichloroethylene, tetrachloroethylene and 1,2(trans)dichloroethylene.

Ten shallow monitoring wells (<50 feet) around H-1 and H-2 showed that the water table aquifer close to the wells was not significantly contaminated. A deeper well (well No. 11) was installed and sampled at close intervals to determine the vertical distribution of contamination. This sampling revealed that the semi-confined aquifer from which the production wells are drawing was contaminated with the target compounds.

As a result of this, the present phase of the investigation was initiated. Fourteen (14) deep monitoring wells were installed to intercept the production aquifer to determine the levels, areal extent and if possible, the source of the contamination and possible remedial measures. An Organic Vapor Analyzer (OVA) Model 128 was used to detect and monitor the presence of organic vapor during well installation. Water samples were collected and analyzed for the target compounds.

A 72-hour pump test was conducted to determine hydraulic characteristics. Water samples were collected from the pumping well and analyzed to determine the change in contaminant concentrations with pumping time.

Analytical results indicate that with the exception of well No. 1, none of the shallow wells is significantly contaminated by the target compounds analyzed. This confirms our previous conclusion (Wolf, Boateng, 1982, unpublished report) that the shallow aquifer is not the source of contamination. Contaminent distribution in well No. 11 also confirms this.

Analysis of the pump test data shows that wells Nos. 16, 20 and 21 located north of H-2 respond quickly and have greater drawdown than other nearby wells. The high levels of the target compounds found in wells No. 16 and 20, coupled with the high pH, conductivity and elevated temperature suggest that the source of the contamination in the production wells H-1 and H-2 is in the immediate vicinity of well No. 20. The source was subsequently identified as a discharge to a septic tank drain field at a laundry and dry cleaners.

Very high levels of methylene chloride were found in well Nos. 12 and 14 during the February 1983 sampling. This compound was not detected in the pumping well, despite drawdowns in the monitoring wells indicating at least some hydraulic connection with H-2. It is probable that the pump test was not sufficiently prolonged. It may also be that these wells lie beyond the area from which the pumping well was drawing water. The water level fluctuations of well No. 13 probably reflect pumping of the wells on the McChord Air Force Base.

It is recommended that contamination from the identified source near well No. 20 be eliminated, and that the production wells be pumped and sampled at intervals after this to see if acceptable levels of water purity are achieved.

If acceptable levels are not achieved within a reasonable time, cost/benefit studies on treating the water or using alternative sources should be done.

A follow-up study should be done to confirm and delineate the methylene chloride contamination.

II. INTRODUCTION

In the summer of 1981, sampling by EPA confirmed that the Lakewood Utility District production wells H-1 and H2 were contaminated with chlorinated hydrocarbons. Earlier sampling had shown strong evidence that these wells were contaminated by trichloroethylene, tetrachloroethylene and 1,2 (trans) dichloroethylene (Littler et. al, 1981). An examination of the "as constructed" well logs for the two production wells revealed that well H-1 appeared to be properly constructed. The annular space around the casing of well H-2 had been filled with porous gravel pack having no cement seal to prevent vertical migration of contaminants from the shallow perched aquifer into the lower production aquifer. The logs also showed the occurrence of till layer at about 25-30 feet from the ground surface. It is believed that the till restricts the vertical movement of water and creates a perched water table. If grossly contaminated, such a perched aquifer could be the source of contamination reaching the deeper aquifer by downward through the annular gravel pack. The concentrations of organics in the lower aquifer were relatively higher in well H-2 than in well H-1 which supports this view.

A preliminary field investigation was therefore initiated in October, 1981. The objective of this study was to probe the upper, perched aquifer in an attempt to define the direction of groundwater movement, and the level and extent of contamination, if any.

Ten shallow wells were installed in the upper zone. Water samples were collected and analyzed for the target compounds.

Analytical results showed that the upper perched zone was not the source of the contamination. It was therefore recommended that a well penetrating the production aquifer (lower aquifer) be drilled near well H-2, the more contaminated of the two production wells, to determine the vertical distribution of contaminants. Data obtained from this well showed that the most contaminated zone occurs within a sand and gravel stratum between 80 to 95 feet from ground elevation.

Based on this information, the second phase of the study was initiated. The objective of this investigation was to determine the levels, areal extent, and if possible, the source of the contamination; and also to recommend possible remedial measures.

The field investigation included the construction of 14 deep wells (wells penetrating the production aquifer), organic vapor monitoring, water sampling and the performance of a pump test. A Century System Organic Vapor Analyzer (OVA) Model 128 was used to detect and monitor the presence of organic vapor during well construction. With this information, it was possible to locate the well screen opposite the most contaminated zone. Water samples were collected, and analyzed. To determine hydraulic characteristics in the aquifer, a 72-hour pump test was conducted. To determine groundwater velocity, a salt solution was introduced at one of the wells, and monitored at the pumping well. Conductivity, pH and temperature were also monitored at the pumping well. Additionally, water samples were collected from the pumping well and analyzed to determine the change in contaminate concentration with pumping time.

This project was carried out under the direction of the Environmental Services Division, U.S. EPA, Region 10 with supporting professional services and contracting support from the Field Investigation Team, Region 10, Ecology and Environment, Inc., under Technical Directive Documents 10-8108-03, 10-8108-03A, 10-8108-03B, 10-8202-01, 10-8202-02, 10-8202-02A, 10-8202-02B, 10-8212-04 and R10-8301-08.

III. PHYSICAL DESCRIPTION

3.1 Location

The Lakewood Water District wells H-1 and H-2 are located approximately 200 feet northeast of the intersection of Interstate-5 and New York Avenue in Lakewood, Pierce County, Washington. Well H-1 is located in the NW1/4 of the NE1/4 of Section 14, Township 19N, Range 2E. Well H-2 which is about 100 feet North of H-1 is located in the SW1/4, SE1/4 of Section 11, Township 19N, Range 2E. This is at latitude 47°08' 30"N and longitude 122°31'15"W (Fig. 1). The site is part of a flat-topped upland which is generally referred to in this report as the Tacoma Upland. The Tacoma Upland slopes gently northwestward and is bordered by the Puyallup River Valley on the northeast, Commencement Bay on the north, Puget Sound on the west, Nisqually River Valley on the southwest and the Ohop Valley on the southeast.

3.2 Climate and Water Budget

The Tacoma Upland (Lakewood-Tacoma general area) has a temperate maritime climate with cool wet winters and warm dry summers. Average annual precipitation from 1945-1980 is 40 inches (DOE, 1981) of which about 85 percent occurs from September through April (Walters and Kimmel, 1968).

The highest temperature occurs during July and August and the lowest during December and January. Since evaporation largely depends on temperature, maximum evaporation potential coincides with periods of minimum precipitation. As a result there is much smaller water loss by evaporation than would otherwise occur if precipitation were distributed more evenly through the year. Furthermore, there is a greater

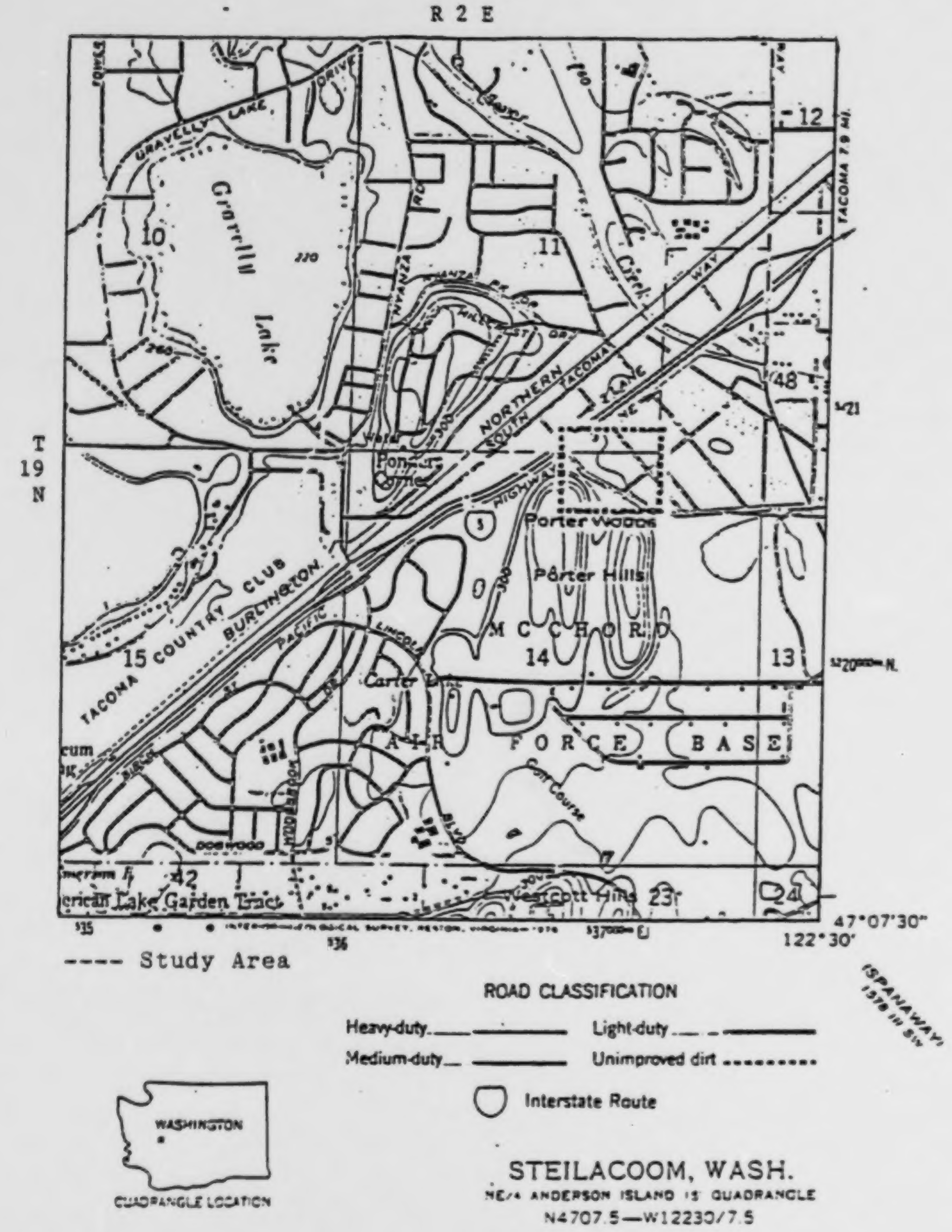

R 2 E
T 19 N
Gravelly Lake
Gravelly Lake Drive
10
11
12
13
14
15
23
24
42
48
Ponders Corner
Porter Woods
Porter Hills
Northern Pacific
South Tacoma Way
Highway
Burlington
Tacoma Country Club
McChord Air Force Base
Carter Lake
Golf Course
Westcott Hills
American Lake Garden Tract
Dogwood
Lincoln
Nyanza
Hillcrest Dr
Tacoma 7.9 mi.
47°07'30"
122°30'
---- Study Area
ROAD CLASSIFICATION
Heavy-duty
Light-duty
Medium-duty
Unimproved dirt
Interstate Route
WASHINGTON
QUADRANGLE LOCATION
(SPANAWAY) 1378 III SW
STEILACOOM, WASH.
NE/4 ANDERSON ISLAND 15' QUADRANGLE
N4707.5—W12230/7.5
1959
PHOTOREVISED 1968 AND 1973
AMS 1478 II NE—SERIES V891

FIGURE 1

LOCATION MAP

LAKEWOOD WATER DISTRICT

runoff and a much greater recharge to aquifers than would otherwise occur (Griffin, et al., 1962). The mean lake evaporation is about 23 inches per year.

3.3 Areal Geology

In their study of the Water Resource of the Tacoma Area, Griffin, et al. (1962) divided the general area into two different geological terranes: the Eastern and the Western parts.

The Eastern part which lies within the foothills of the Cascade Range, is underlain by volcanic, metamorphic and consolidated sedimentary rocks of Eocene and Miocene age.

The Western part which covers the study area is underlain by a great thickness of semi-consolidated and unconsolidated sediments laid down in lakes or by streams during Holocene, Pleistocene and late Tertiary time. These sediments include clay, silt, sand and gravels, glacial till and peat; their combined thickness range from nil to more than 2000 feet.

Water bearing characteristics in the general area differ from place to place depending upon rock type. The rock underlying the Eastern part generally have low permeability and yeild very little water to wells. The sediments underlying the Western part of the area vary in degree of permeability. Glacial outwash sand and gravel deposits generally have high permeability and where saturated are productive aquifers. Clay, peat and till strata are characterized by low permeability and are much less productive, yielding only small amounts of water to wells.

3.4 Site Geology

The study area is underlain by Steilacoom gravels. These were deposited in large meltwater streams that flowed westward across the area during the retreat of the Puget ice lobe (Walters and Kimmel, 1968). This unit consists of coarse sand and gravels with cobbles, and is consistently coarse over a large area. This characteristic distinguishes the Steilacoom gravels from other outwash deposits. The unit was encountered in all the monitoring wells; and its thickness ranges from one foot to 35 feet.

Underlying the Steilacoom gravels is the Vashon till. This unsorted mixture of clay, silt, sand and gravels, cobbles and boulders was deposited beneath the ice sheet and compacted by the weight of the ice. The till is grey and has the general appearance and characteristics of concrete. It is very tough to drill through, and drillers usually refer to it as "hardpan". The thickness of this unit ranges from three to 36 feet in the study area, and was encountered in all the monitoring wells.

Advance outwash deposits underlie the Vashon till. These deposits were laid down by meltwater streams during the advance of the ice. The unit generally consists of well sorted stratified gravels and cobbles with sand and clay lenses. The advance outwash gravels were encountered in all the monitoring wells. The advance outwash overlies the Colvos Sands, and the contact between these two units is sometimes not readily apparent due to the similarities of their lithology.

The Colvos Sands generally consist of well sorted sands with lenses of gravel. The basal portion of the unit consists of blue clay, probably deposited in proglacial lakes that formed in front of the advancing ice. The Colvos Sands were encountered in some of the monitoring wells.

3.5 Hydrology

The Tacoma Upland encompasses about 360 square miles and receive an average annual rainfall of about 40 inches. Precipitation is the major source of groundwater recharge, though locally the groundwater is artificially recharged by water imported to the upland from the Green River. Griffin, et al. (1962) estimate that the entire upland receives about 730,000 acre- feet of water per year, and that between 50 to 60 percent of this may become groundwater. In the Lakewood area, Clover Creek recharges the groundwater body upgradient from Steilacoom Lake.

Most of the groundwater discharge occurs through pumping for municipal and industrial uses, through streams, springs and seeps, and, around the margins of the upland, into the Puyallup River or directly into Puget Sound.

The lakes in the Lakewood area are water-table lakes and lose and gain water in about equal quantities.

In the study area, the direction of groundwater flow is west northwest towards Gravely Lake. The slope of the water table is very irregular, and ranges from 120 feet per mile in impermeable materials to less than 10 feet per mile in highly permeable materials. (Walters and Kimmel, 1968). In the study area, the average slope of the water table is about 15 feet per mile.

The most important aquifers in the Tacoma Upland are the outwash sand and gravel deposits of Vashon age, and the sand and gravel deposits of Pre-vashon age (Fig. 2). The outwash deposits mantle the surface of the central part of the upland, while the Pre-Vashon deposits underlie the entire upland but crop out only at the margins of the upland.

In the Lakewood area, the Steilacoom gravels generally contain water perched above the regional water table by impermeable Vashon till. This unit generally yields water to shallow wells except in areas where deposits are thin or where they lie above the water table and do not contain water. The advance outwash deposits have an average thickness of about 100 feet and are the most productive aquifers in the Lakewood area. Although these sediments contain a larger proportion of sand than the recessional outwash deposits, locally they have transmissibilities of 2,000,000 gpd per foot (Griffin, et al, 1962). One of the contaminated wells, well H-1, is 110 feet deep and taps water from the advance outwash deposits. This well yields more than 2,000 gpm with a specific capacity of about 35 gpm per foot of drawdown. Water table contours for this region are shown in Figure 3.

The Pre-vashon deposits also contain important aquifers, they are less permeable and generally have lower transmissibilities than those of the outwash aquifers, however.

3.6 Groundwater Quality

Generally, groundwater of the Tacoma Upland is of good quality and satisfactory for public use. Average concentrations of dissolved solids in samples collected from 36 wells

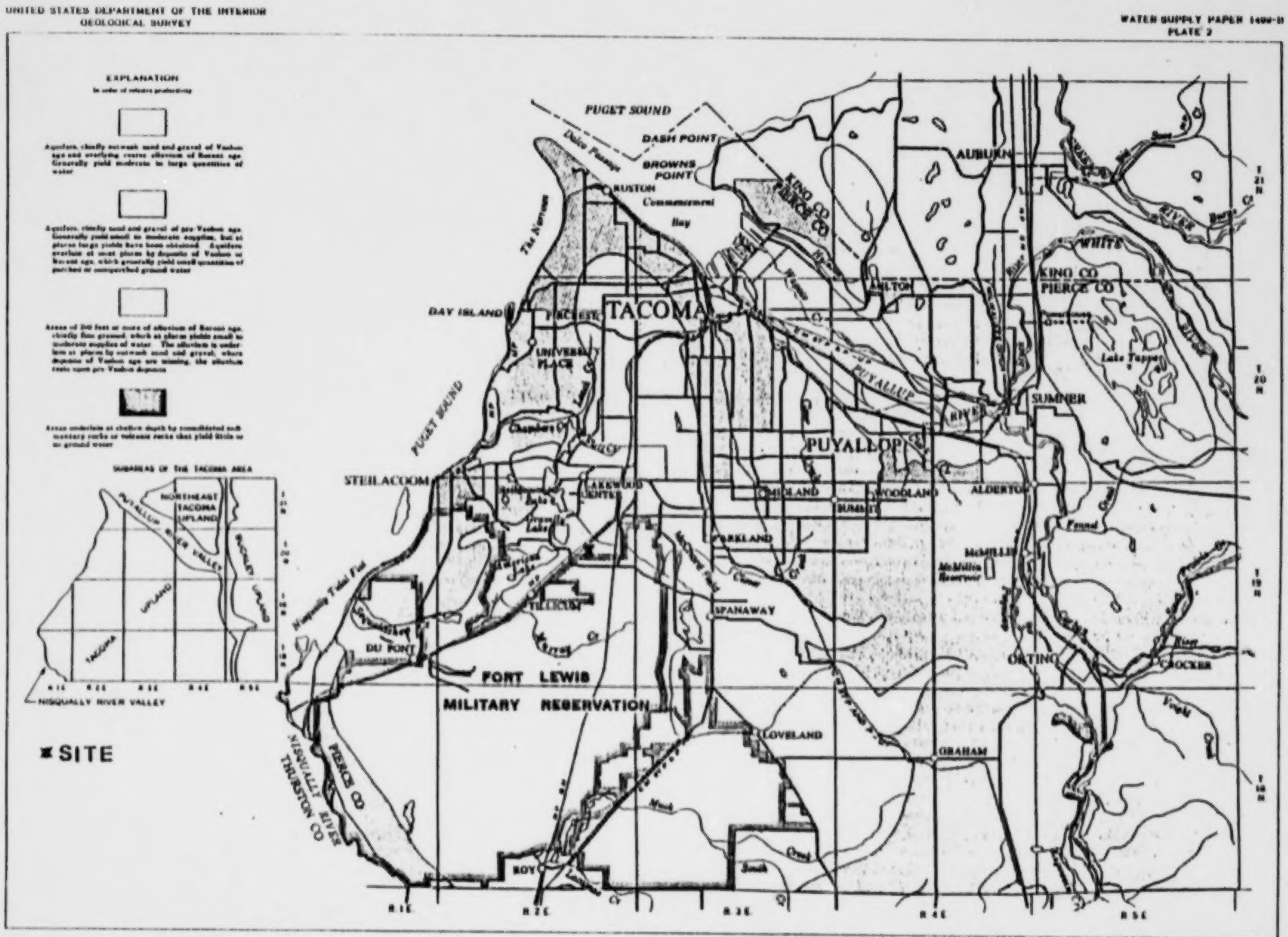

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER SUPPLY PAPER 1499-B
PLATE 2
EXPLANATION
In order of relative productivity
Aquifers, chiefly outwash sand and gravel of Vashon age and overlying coarse alluvium of Recent age. Generally yield moderate to large quantities of water
Aquifers, chiefly sand and gravel of pre-Vashon age. Generally yield small to moderate supplies, but at places large yields have been obtained. Aquifers overlain at most places by deposits of Vashon or Recent age, which generally yield small quantities of perched or unconfined ground water
Areas of 200 feet or more of alluvium of Recent age, chiefly fine grained, which at places yields small to moderate supplies of water. The alluvium is underlain at places by outwash sand and gravel; where deposits of Vashon age are missing, the alluvium rests upon pre-Vashon deposits
Areas underlain at shallow depth by consolidated sedimentary rocks or volcanic rocks that yield little or no ground water
SUBAREAS OF THE TACOMA AREA
NORTHEAST TACOMA UPLAND
PUYALLUP RIVER VALLEY
BUCKLEY UPLAND
UPLAND
TACOMA
NISQUALLY RIVER VALLEY
SITE
PUGET SOUND
DASH POINT
BROWNS POINT
RUSTON
Dalco Passage
The Narrows
Commencement Bay
KING CO
PIERCE CO
AUBURN
MILTON
DAY ISLAND
TACOMA
UNIVERSITY PLACE
Chambers Cr
PUYALLUP
RIVER
WHITE RIVER
SUMNER
Lake Tapps
STEILACOOM
LAKEWOOD CENTER
MIDLAND
SUMMIT
WOODLAND
ALDERTON
PARKLAND
SPANAWAY
McMILLIN
McMillin Reservoir
Nisqually Tidal Flat
DU PONT
FORT LEWIS
MILITARY RESERVATION
ORTING
CROCKER
Carbon River
LOVELAND
GRAHAM
ROY
Muck
South Creek
NISQUALLY RIVER
PIERCE CO
THURSTON CO
T 21 N
T 20 N
T 19 N
T 18 N
R 1 E
R 2 E
R 3 E
R 4 E
R 5 E

FIGURE 2: AQUIFER MAP OF THE TACOMA AREA

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-SUPPLY PAPER 1499-B
PLATE 3

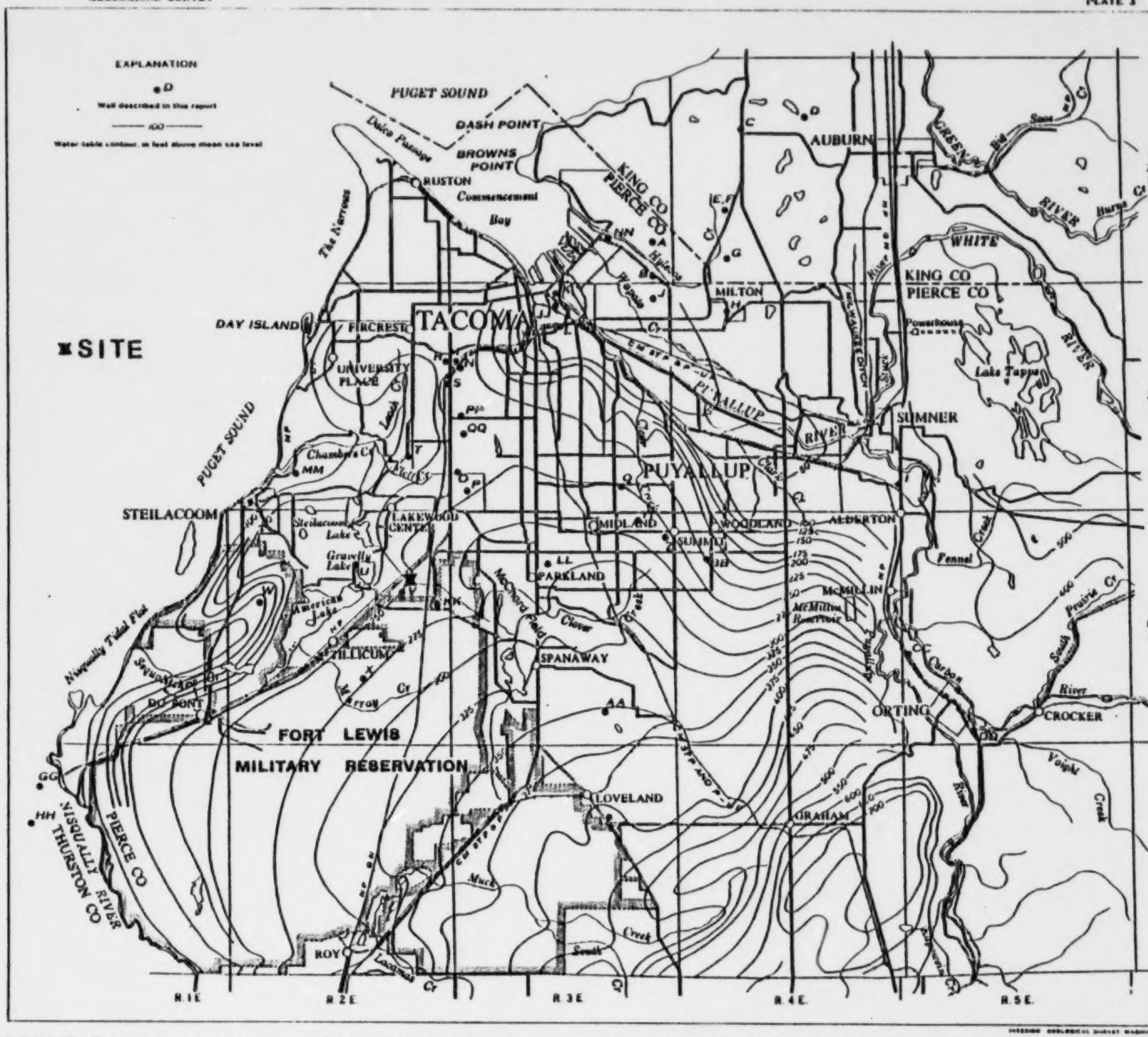

EXPLANATION
D
Well described in this report
100
Water-table contour, in feet above mean sea level
SITE
PUGET SOUND
DASH POINT
BROWNS POINT
RUSTON
Commencement Bay
Dalco Passage
The Narrows
DAY ISLAND
FIRCREST
TACOMA
UNIVERSITY PLACE
KING CO
PIERCE CO
AUBURN
MILTON
SUMNER
PUYALLUP
RIVER
WHITE
GREEN
Lake Tapps
Powerhouse
STEILACOOM
Steilacoom Lake
Gravelly Lake
LAKEWOOD CENTER
Chambers Cr
American Lake
TILLICUM
MIDLAND
SUMMIT
WOODLAND
ALDERTON
PARKLAND
McChord Field
Clover Creek
SPANAWAY
McMILLIN
McMillin Reservoir
ORTING
CROCKER
South Prairie Cr
Carbon
Fennel Creek
Voight Creek
LOVELAND
GRAHAM
Muck Creek
South Creek
ROY
Lacamas Cr
FORT LEWIS
MILITARY RESERVATION
Nisqually Tidal Flat
Sequalitchew
DU PONT
NISQUALLY RIVER
PIERCE CO
THURSTON CO
EE
GG
HH
AA
LL
MM
PP
QQ
KK
T 21 N
T 20 N
T 19 N
T 18 N
R.1E.
R.2E.
R.3E.
R.4E.
R.5E.
MILES

FIGURE 3: WATER-TABLE CONTOURS AND SELECTED OBSERVATION WELLS IN THE TACOMA AREA

and springs was 95 ppm, while average hardness of the samples was 48 ppm (Griffin, et al., 1962). Wells in the outwash deposits yield water in which concentrations of dissolved solids range from 92 to 105 ppm, hardness ranges from 53 to 65 ppm, and silica from 23 to 34 ppm. The Pre-Vashon deposits yield water in which the concentrations of dissolved solids range from 70 to 108 ppm, hardness ranges from 35 to 57 ppm and silica from 24 to 50 ppm (Fig. 4).

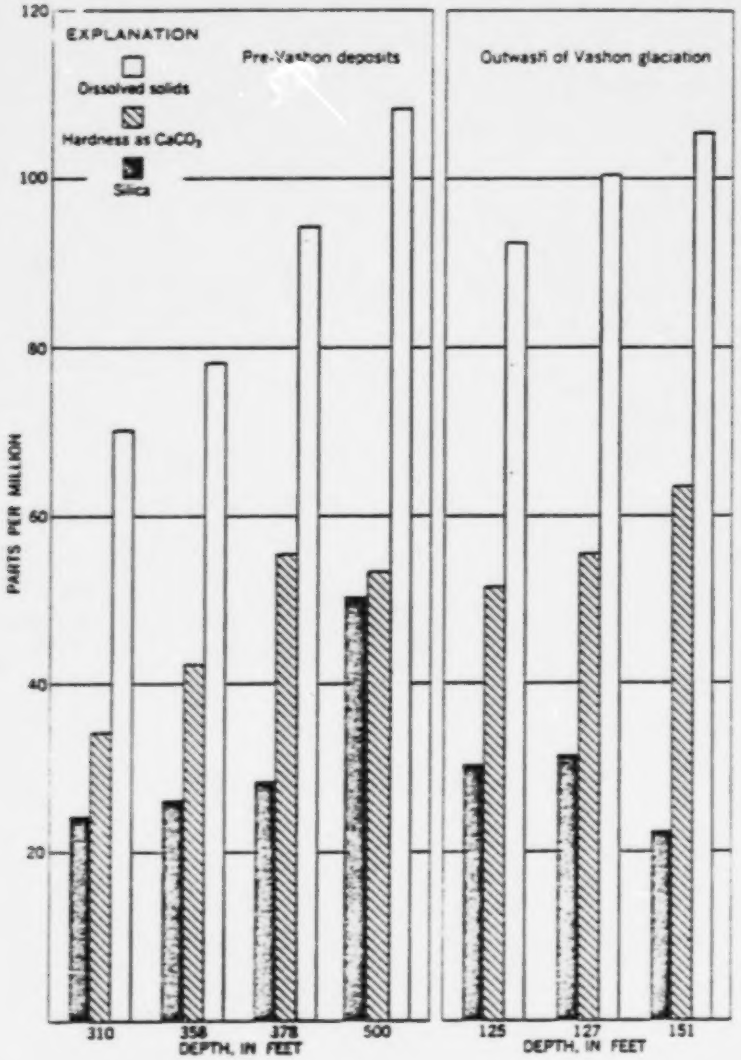


FIGURE 4
GROUNDWATER QUALITY IN
SAND AND GRAVEL AQUIFERS*
LAKEWOOD WATER DISTRICT

*USGS Water Supply Paper

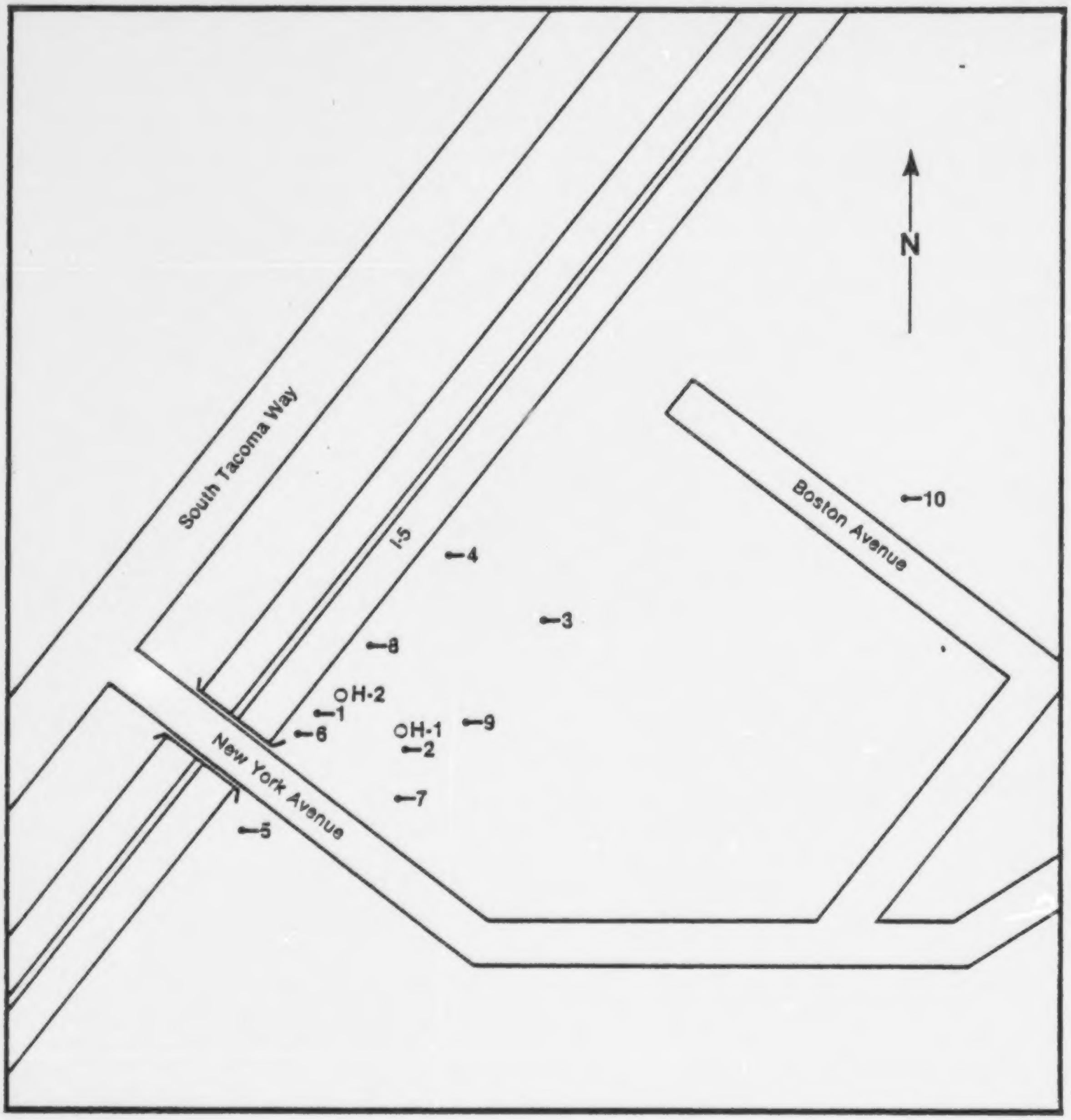
IV. METHODOLOGY

4.1 Site Selection

Drilling sites were preselected by the investigators to allow adaquate time to obtain permission to drill, and to ensure rig access. Individual sites selected for drilling were based on field judgement and OVA data. Each well site was chosen on the basis of information gathered in preceeding wells. The flexibility inherent in this approach permitted more data to be obtained using fewer drill sites. A map showing locations of the shallow monitoring wells is presented in Figure 5, and of the deep monitoring wells in Figure 6. Well logs are included in Appendix A.

4.2 Well Construction-Shallow Monitoring Wells

These monitoring wells were excavated to an average depth of 35 feet, about 10 feet below the water table, utilizing a truck-mounted hollow-stem auger drill (Mobile Drill D-61). The internal diameter (ID) of the auger was 4 inches. A 2-1/2 inch (ID) ungalvanized steel casing (black iron pipe), was then installed. The casing had torch-cut perforations extending over the bottom 10 feet (except in observation wells No. 1 and 2 which were 20 and 15 feet long respectively). Since the formation material is coarse, it was not necessary to place gravel pack around the perforations to serve as a filter media.


South Tacoma Way
I-5
N
Boston Avenue
New York Avenue
10
4
3
8
H-2
1
6
H-1
9
2
7
5

*Not Drawn to Scale

Well Location Map*
Lakewood Washington

○ Lakewood Water District Production Well
⸺ Monitoring wells Installed by EPA

FIGURE 5
LOCATION OF SHALLOW MONITORING WELLS
LAKEWOOD WATER DISTRICT

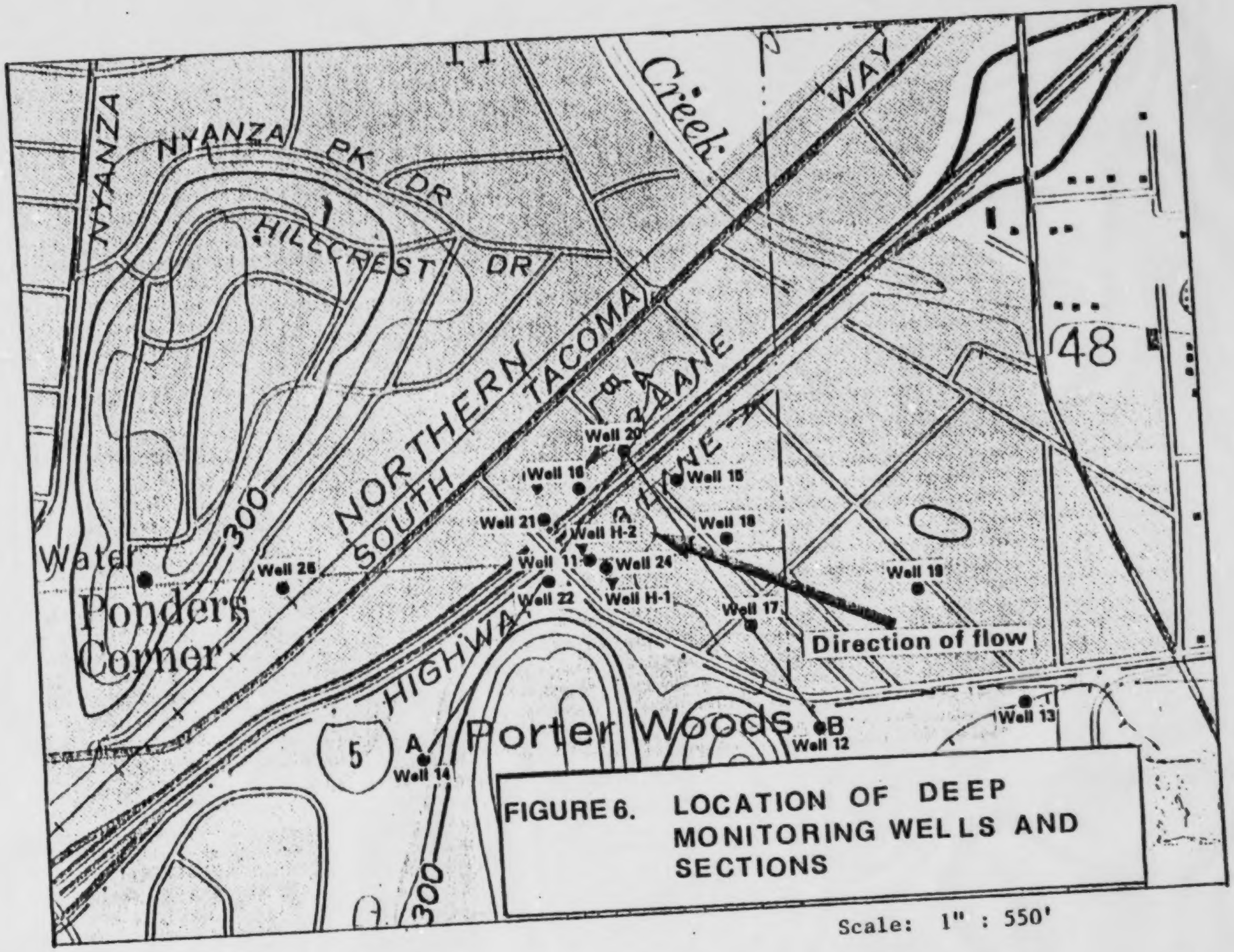

NYANZA
NYANZA PK DR
HILLCREST DR
Creek
WAY
NORTHERN
SOUTH TACOMA
LANE
LANE
300
300
Water
Ponders Corner
Well 28
Well 20
Well 16
Well 15
Well 21
Well H-2
Well 18
Well 11
Well 24
Well 22
Well H-1
Well 17
Well 19
Direction of flow
HIGHWAY
5
A
Well 14
Porter Woods
B
Well 12
Well 13
48

FIGURE 6. LOCATION OF DEEP MONITORING WELLS AND SECTIONS

Scale: 1" : 550'

The annular space from the top of the perforations to 6 feet below ground surface was backfilled with drill cuttings. The annular space from the depth of 6 feet to ground surface was filled with a mixture of bentonite and fine sand in a ratio of one portion of fine sand and one portion of bentonite in accordance of Washington State Department of Ecology (DOE) specifications. Details of well construction are illustrated in Figure 7.

4.3 Well Construction-Deep Monitoring Wells

These monitoring wells were excavated with a cable tool drill rig. The hole was cased utilizing unperforated steel casing with a drive shoe. The diameter of the hole was 8 inches. While drilling from the water table to the final depth, the casing was advanced so that the open hole did not extend more than a foot below the bottom of the casing. As small a quantity of water as possible was added to the hole during drilling.

After the hole had been excavated to the required depth, 2-inch (ID) Polyvinyl chloride casing with perforations at the bottom was placed inside the 8-inch casing. The perforated section (screen) of the casing was usually 10 feet long; and was placed opposite the most contaminated zone. The most contaminated zone was identified with the OVA. Uniform pea gravel was then placed in the annulus of the well around the 2-inch PVC casing and inside the 8-inch steel casing to serve as a filter media.

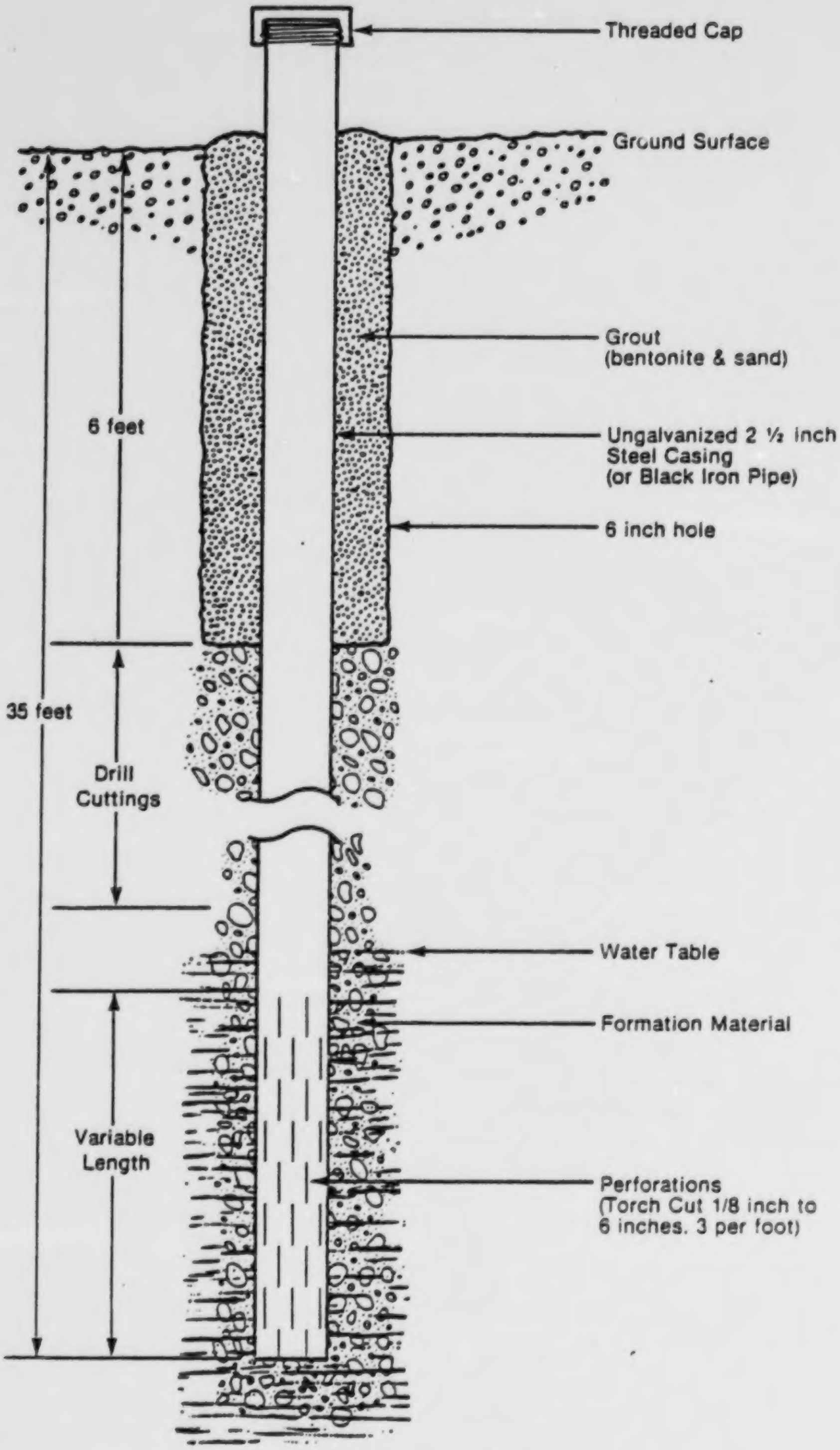
The 8-inch steel casing was gradually withdrawn during placement of the gravel pack and the cement seal. This was done in a manner that did not cause damage to the PVC casing

FIGURE 7

Monitoring Well Construction* SHALLOW WELLS

Lakewood Project

*Not Drawn to Scale


Threaded Cap
Ground Surface
Grout
(bentonite & sand)
6 feet
Ungalvanized 2 ½ inch
Steel Casing
(or Black Iron Pipe)
6 inch hole
35 feet
Drill
Cuttings
Water Table
Formation Material
Variable
Length
Perforations
(Torch Cut 1/8 inch to
6 inches. 3 per foot)

or cause excessive caving. For example, after filling 2 feet with gravel, the 8 inch steel casing was withdrawn 2 feet. This step of placing more gravel and withdrawing the outer casing was repeated until the level of the gravel was about 3 feet above the screen.

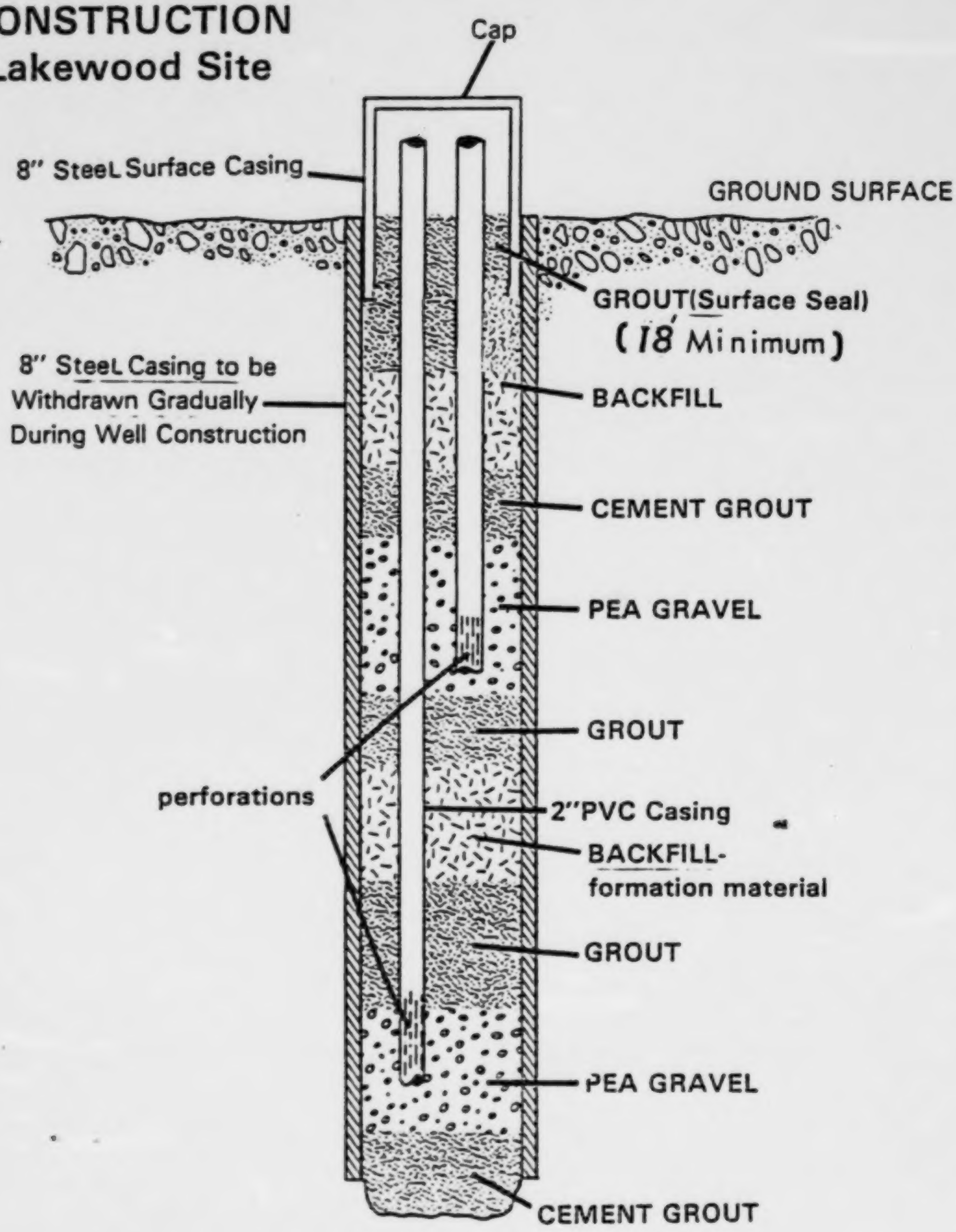
To prevent possible migration of contaminants along the well casing, the well annulus was grouted with a cement/bentonite seal. Where two distinct contaminated zones existed , both zones were screened and the space between them sealed off to prevent possible cross-contamination (Fig. 8).

4.4 Monitoring With The OVA

A Century Systems Organic Vapor Analyzer (OVA) Model 128 was used to detect and monitor the presence of organic vapor during and after well installation. Twofold methods were used; survey mode and the chromatographic (GC) mode. The survey mode was used to "sniff" the wells during drilling to determine if organic vapors were encountered (Fig. 9). The GC mode was used to identify specific organic compounds. An HNU Model 101 Photoionization Analyzer was used to screen for methane.

A field operational base was set up at the Environmental Engineering Department Laboratory at the McChord Airforce Base. The laboratory was sufficiently close to the drill sites to allow samples to be collected and analyzed within minutes. The laboratory also offered constant temperature operating conditions for the OVA in the chromatographic mode.

TWO LEVEL MONITORING WELL CONSTRUCTION Lakewood Site


Cap
8" Steel Surface Casing
GROUND SURFACE
GROUT(Surface Seal)
(18' Minimum)
8" Steel Casing to be Withdrawn Gradually During Well Construction
BACKFILL
CEMENT GROUT
PEA GRAVEL
GROUT
perforations
2"PVC Casing
BACKFILL-formation material
GROUT
PEA GRAVEL
CEMENT GROUT

Not to Scale

FIGURE 9

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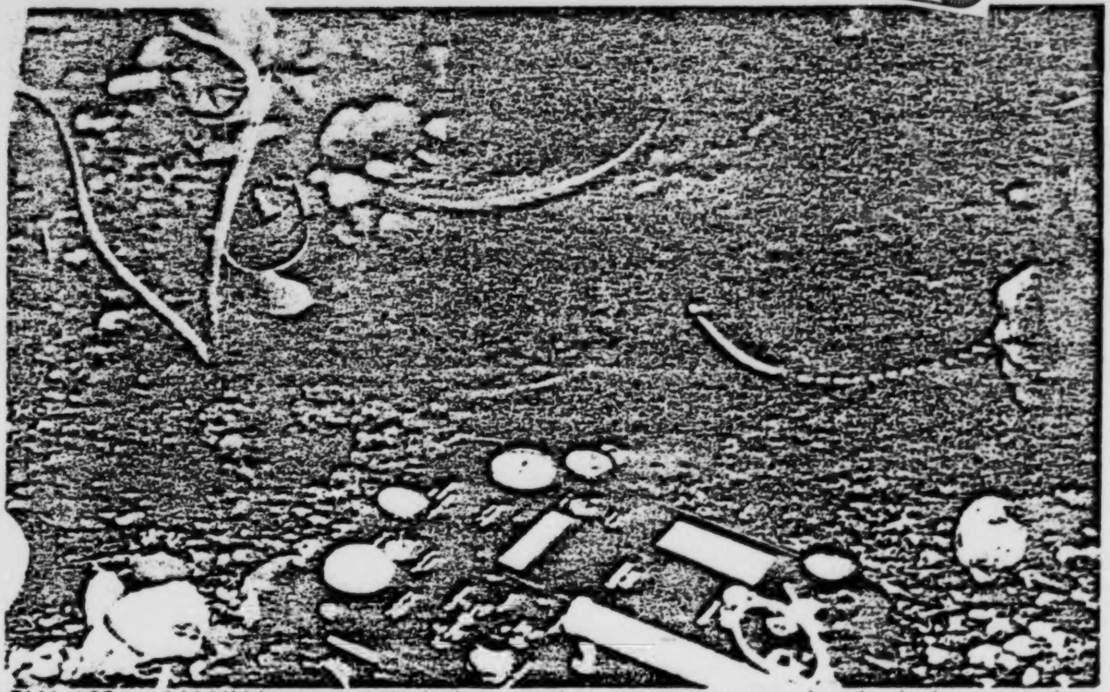
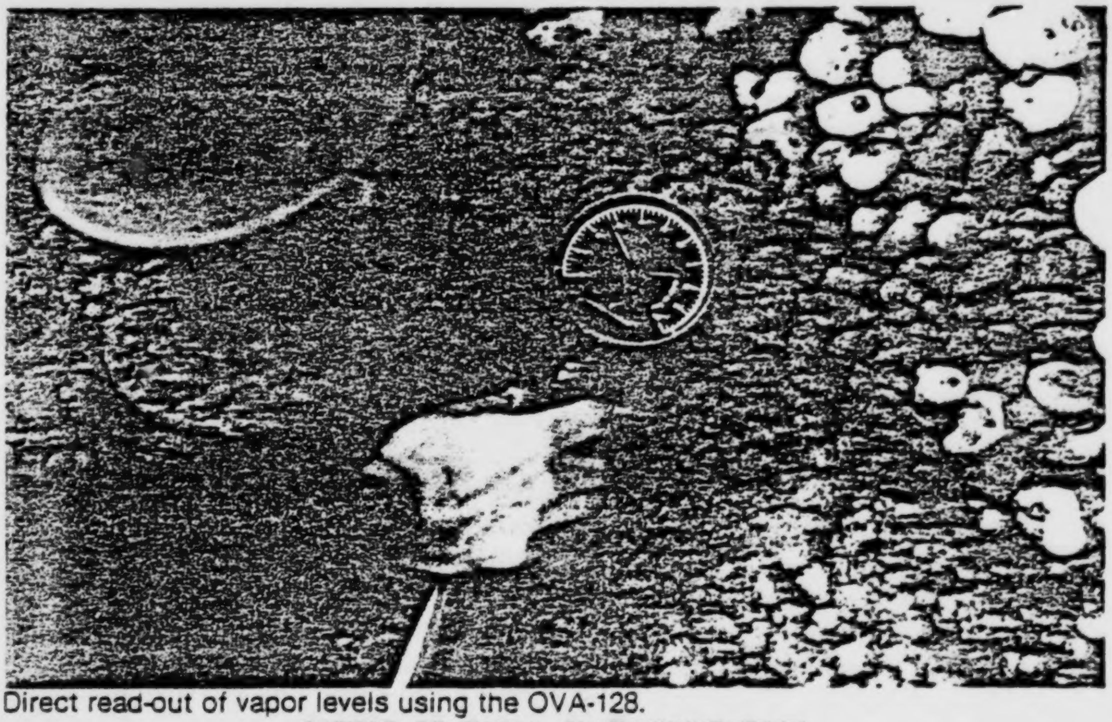


OVA-128 and H-NU instruments being used to measure vapor levels during augering.



Direct read-out of vapor levels using the OVA-128.

PHOTOS OF FIELD INSTRUMENTATION
LAKEWOOD WATER DISTRICT

Water samples were collected at one-foot intervals while drilling, and analyzed in the GC mode to identify specific organic compounds by comparison with their standards. With this information, it was possible to set the well screen opposite the most contaminated zone. Where there were two separate contaminated zones, a two-level monitoring well construction system was installed to tap both zones (Fig. 8). This procedure allowed field personnel to screen the samples to decide which were to be sent to the EPA laboratory for more detailed analysis. However, all samples taken from wells Nos. 17-25 were sent to the laboratory.

4.4.1 Survey Mode

Background levels of organics at the general area were recorded with the OVA in the survey mode. Total organics measured fluctuated from 2-5 ppm. This was probably due to the close proximity of the drilling sites to Interstate Highway 5. Some of the drilling sites were close to and sometimes downwind of the highway. Using the OVA in the survey mode, all the drilling equipment and drilling materials such as pea gravel, cement and well casings were checked. On several occasions bags of pea gravel were found to be contaminated with gasoline and were therefore excluded from the well construction. At no time were OVA readings above the background levels of 2-5 ppm observed in the breathing zone around the wells.

4.4.2 Chromatographic (GC) Mode

In the chromatographic methodology, retention times are used to identify "unknown" compounds present in samples. To accomplish identification, standards are run and retention times matched. In this case four target compounds were expected: 1,2-transdichloroethane; tetrachloroethylene trichloroethylene, and 1,1,1-trichloroethane. Standards were run each day of drilling, and retention times compared. As it was possible to keep the column at a constant temperature of about 20°C at all times at the McChord laboratory, retention times for the standards fluctuated very little.

The columns used in the study were type T-12, containing 10 percent 1,2,3-tris-(2-cyanoethyoxy) propane or chromosorb P, AW, 60/80 mesh and type G-24 containing 10 percent SP-2100 on supelcoport, 60/80 mesh. Both columns gave excellent separation of the target compounds.

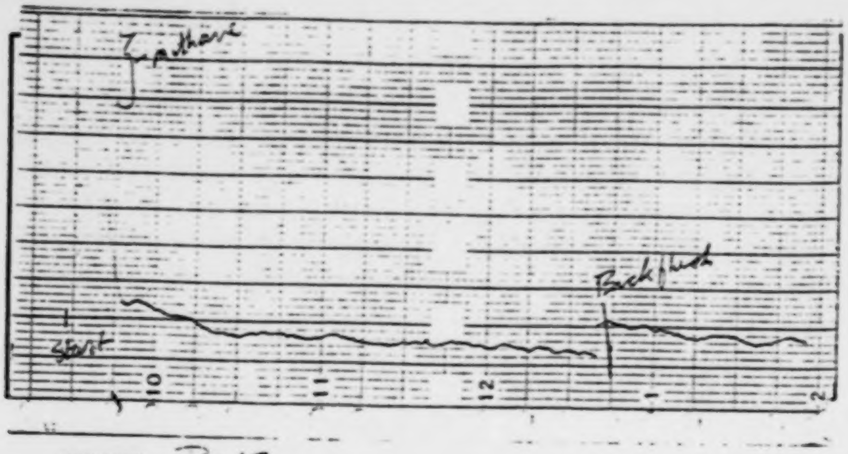
Water samples were placed in 40-ml vials with teflon septa. The vials were then placed in a water bath and heated to 40°C. Prior to sample injection, the vials were shaken for about one minute, and placed in the water bath again to equilibrate.

A 500 ul sample of the headspace was collected in a Hamilton gas-tight syringe and injected into the OVA. Representative chromograms are illustrated in Figures 10, 11, 12, and average retention times for each compound are given.

4.5 Well Development

The completed wells were developed with compressed air to ensure their utility as monitoring wells. In the two-level monitoring well construction system, each level was developed separately. This was done in a manner that did not cause any undue disturbances to the strata around the well casing and thereby reduce the surface seal. The development of the wells coninued until the water pumped from the wells was clear and free of sand. This usually took one and a half to two hours per well.

TDD: 10827202A **DATE:** 8/25/82



COLUMN R-12

TYPE OF INJECTION GC

STANDARD(S) Sample from 95 ... -14

TEMPERATURE 20.0°C **COLUMN FLOW RATE** 10 psi

RANGE SETTING X1 Span 10.0 **RECORDER SETTING** H

INJECTION VOLUME 250 ul **DILUTION FACTOR** ______

QUALITATIVE/QUANTITATIVE ANALYSIS

PEAK NO.	QUALITATIVE ID	QUANTITATIVE	GC/MS CONFIRMATION	COMMENT

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COMMENTS: Clean **OPERATOR:** PCE

FIGURE 10
FIELD CHROMATOGRAM WELL 18
LAKEWOOD WATER DISTRICT

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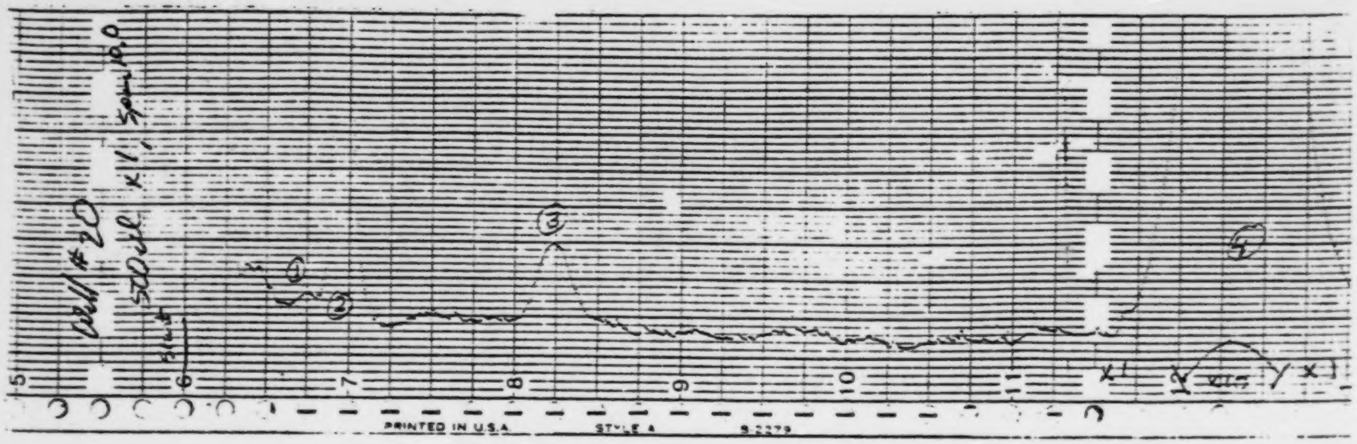
TDD: 0820108

DATE: 2/18/83



COLUMN G24

TYPE OF INJECTION EG

STANDARD(S) Sample from Well 20 B

TEMPERATURE 25.6°C **COLUMN FLOW RATE** 10.9 psi

RANGE SETTING x1, Span 10.0 **RECORDER SETTING** Hi

INJECTION VOLUME 500 ul **DILUTION FACTOR** ____________

QUALITATIVE/QUANTITATIVE ANALYSIS

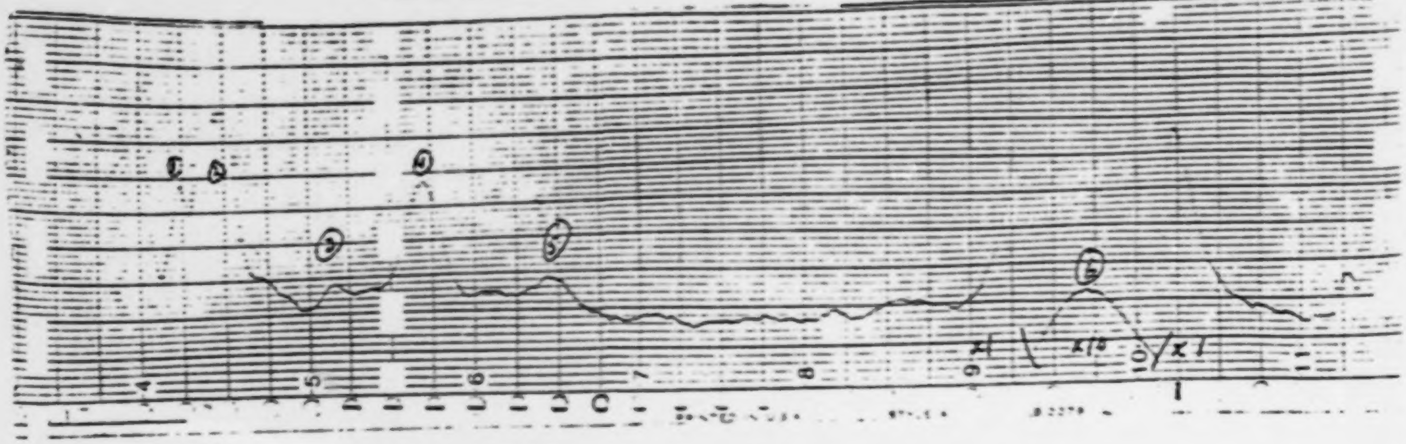
PEAK NO.	QUALITATIVE ID	QUANTITATIVE	GC/MS CONFIRMATION	COMMENT
①	1,2 trans			
②	?			
③	TCE			
④	Tetra			

COMMENTS:

OPERATOR:

FIGURE 11
FIELD CHROMATOGRAM WELL 20B
LAKEWOOD WATER DISTRICT

TDD: 1082020Z4   DATE: 12/28/82



COLUMN G24

TYPE OF INJECTION GC

STANDARD(S) Sample from Well# 24 at 97ft

TEMPERATURE ~~22~~ 27.0°C   COLUMN FLOW RATE 10.1 psi

RANGE SETTING x1, span 10.0   RECORDER SETTING Hi

INJECTION VOLUME 500 ul   DILUTION FACTOR

QUALITATIVE/QUANTITATIVE ANALYSIS

PEAK NO.	QUALITATIVE ID	QUANTITATIVE	GC/MS CONFIRMATION	COMMENT
①	1,2-trans			
②	?			
③	maybe 1,1,1 tri			
④	TCE			
⑤	?			
⑥	tetra			

COMMENTS:

OPERATOR: PCE

FIGURE 12
FIELD CHROMATOGRAM WELL 24
LAKEWOOD WATER DISTRICT

4.6 Survey

Elevations of the top of the well casings were surveyed in to the mean sea level (MSL). This was necessary to determine the direction of groundwater flow at the site. All water level measurements were taken from this datum. Distances and directions of monitoring wells from Well H-2 were also measured and are presented in Table 1.

4.7 Equipment Decontamination

The project required the use of equipment decontamination procedures to ensure that trace levels of volatile organic compounds were not the result of cross-contamination between drill sites nor from sources outside the project area. Outside sources of contamination could include trucks used to haul drilling equipment, or drilling equipment in contact with contaminated surfaces. The drilling contractors were required to provide two complete sets of "down-the-hole" drilling equipment; strings of auger, drill bits, etc. This permitted one set of equipment to be in use while the other was being cleaned and decontaminated off- site. Prior to arrival on-site, the drilling equipment was steam cleaned. One technician and a driller's helper were responsible for operating the off-site decontamination station, located at the Lakewood Water District's equipment storage area. This station also served as a water source for the drilling rig where pre-analyzed water was available in adequate supply. A steam cleaner was obtained by the contractor for this project. The tank of this cleaner was scrubbed with "Alconox" and water, and thoroughly rinsed before it was used. The water tank on the rig was similarly rinsed and then steam cleaned.

TABLE 1
DISTANCE FROM THE PUMPED WELL (H-2) TO MONITORING WELLS
LAKEWOOD WATER DISTRICT

Well Number	Distance (feet)	Bearing
H-1	80	140°
11	15	140°
12	1110	130°
13	2100	112°
14	950	220°
15	450	60°
16	300	360°
17	700	120°
18	550	90°
19	1200	100°
20	400	30°
21	200	312°
22	180	140°
24	30	120°
25	1100	267°

Equipment decontamination during the drilling phase occured as follows:

1. The truck carrying the augers was unloaded at the decontamination site, then scrubbed with Alconox and water followed by steam cleaning.

2. All "down-the-hole" drilling equipment and tools were scrubbed with Alconox and steam cleaned in the same manner and reloaded onto the truck without being set on the ground.

Since cleaning was carried out on a paved surface, drainage was controlled and directed to the sewer system.

Equipment used in the project was periodically checked with both the OVA-128 and HNU vapor detector systems. No organic vapors were detected on tools or auger sections decontaminated by this procedure.

4.8 Pump Test

A pump test to determine the hydraulic characteristics of the aquifer was conducted on February 10, 1983. The test was carried out by pumping well H-2 at 1000 gallons per minute for 72 hours while measuring drawdown in the pumping and other observation wells. Water level measurements in wells Nos. H-1, H-2, 15, 16, 17, 18, 20, 21, and 22, were measured utilizing the Johnson-Petur™ model C-108 water level monitoring system. This system consists of a standard 8-channel pneumatic multiplexer, a controller-readout unit containing two additional sensor channels, a printer, 3/16-inch (O.D.) nylon surface airline tubing and miscellaneous accessories.

Airline tubing was installed in nine monitoring wells to a depth below the anticipated maximum drawdown. Water levels were measured by pneumatic sensors contained in the controller readout and multiplexer units, and attached to the airlines (Fig.13).

In order to operate the pneumatic sensors, nitrogen gas was used. Readout of water levels were programed so that the timing of automatic sequential readouts and water level changes were printed on a strip chart recorder in tenths of minutes and tenths of feet, respectively. Accuracy for the depth determined is 0.1 percent (0.12 ft.); sensitivity is 0.0022 percent (0.003 ft.). Water level measurements in wells Nos. 3, 4, 8 through 14 and 25 were measured using electric tapes.

Complete water level elevation data are in EPA files. Drawdown curves were derived and are also on file. To determine concentration gradient with pumping time, water samples were collected from the pumping well at the following intervals 1-2 minute intervals for 10 minutes; 10 minute intervals for 30 minutes, 30 minute intervals for 6 hours; 60 minute intervals for 6 hours, and then at 12 hour intervals. Samples were analyzed for the target compounds (Table 2,) and for pH, conductivity and temperature (Table 3).

Water from the pumping well was discharged into Clover Creek. Water samples were collected from the creek before, during and after the pump test to determine if contaminants were introduced into the creek. No changes in the levels of chlorinated hydrocarbons were detected.

In an attempt to determine the groundwater velocity, a salt solution (50 lbs. NaCl dissolved in 55 gallons of water) was introduced at well No. 17. Conductivity, pH and temperature were monitored at the pumping well, but no change in conductivity indicating the arrival of the salt was observed. After the well had been pumped for 72 hours, the pump was shut off, and the wells allowed to recover. Water level measurements were taken as they recovered.

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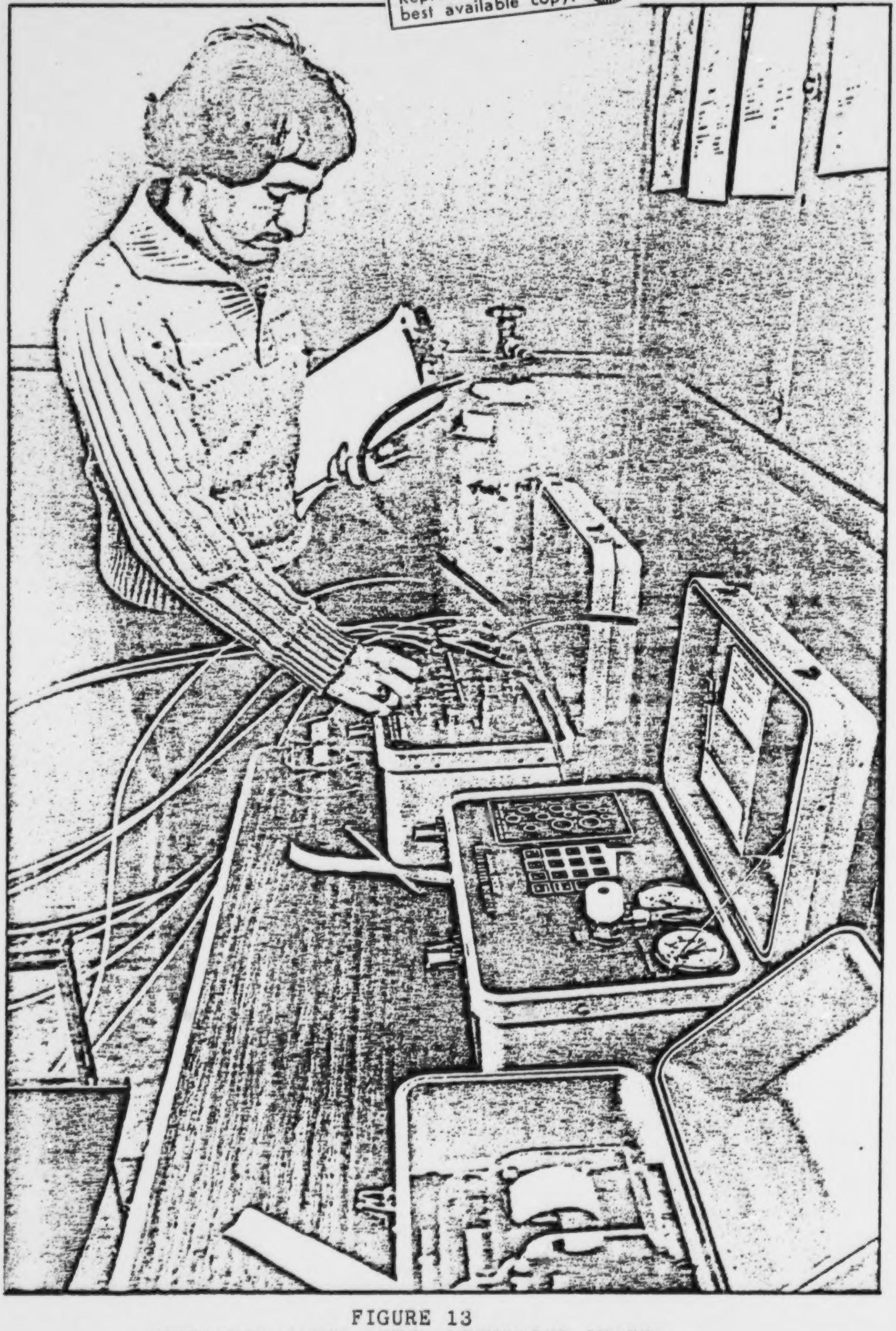

FIGURE 13
AUTOMATIC WATER LEVEL RECORDING SYSTEM
LAKEWOOD WATER DISTRICT

TABLE 2
TIME SERIES CHEMICAL DATA COLLECTED DURING H-2 PUMP TEST LAKEWOOD WATER DISTRICT

Date	Time (Minutes From Start Of Pumpage)	1,2(trans)-dichloro-ethylene (ug/1)	Trichloro-ethylene (ug/1)	Tetrachloro-ethylene (ug/1)
2-10-83	0	200	24	570
	2	255	30	750
	4	265	34	785
	6	265	34	790
	8	265	34	845
	10	275	34	805
	20	300	38	885
	30	315	38	855
	40	320	40	850
	70	340	46	825
	100	310	39	755
	130	320	40	735
	160	310	37	745
	190	330	38	725
	220	330	38	730
	250	270	32	590
	280	280	31	590
	310	270	28	570
	340	270	29	550
	370	265	28	525
	400	255	27	520
2-11-83	1120	268	26	417
	1840	220	25	345
2-12-83	2560	200	18	315
	3280	175	15	295
2-13-83	4000	155	11	285

Table 3

LAKEWOOD PROJECT - PUMP TEST HYDRO LAB DATA

TDD No: R10-8301-08
Well No.: H-2

Date	Time Since Pumping Started (in min.)	Conductivity umhos	pH	t (°C)
2-10-83	0			
	15	293	6.3	---
	25	294	5.6	---
	35	296	5.5	12.9
	60	300	5.5	12.9
	90	301	5.5	12.9
	120	302	5.5	12.8
	160	302	5.5	12.9
	210	303	5.5	12.9
	241	302	5.5	12.7
	278	302	5.6	12.9
	300	302	5.5	12.6
	335	301	5.7	12.7
	366	301	5.8	12.6
	395	300	5.8	12.6
	430	300	5.8	12.6
	460	299	5.9	12.6
	490	299	5.9	12.5
	520	298	5.9	12.5
	550	298	5.9	12.5
	580	298	5.9	12.4
	630	297	6.0	12.5
2-11-83	695	296	5.9	12.7
	758	295	5.9	12.8
	780	295	5.9	12.8
	812	294	5.9	12.8
	872	294	5.9	12.8
	932	293	5.9	12.8
	992	292	5.6	12.8
	1052	290	5.5	12.8
	1090	290	5.5	12.8
	1140	289	5.6	12.8
	1172	289	5.6	12.8
	1294	287	5.6	12.8
	1354	286	5.6	12.8
	1414	286	5.6	12.8
	1491	284	5.8	12.8
	1528	284	5.8	12.8
	1611	283	5.8	12.7
	1652	282	5.8	12.7
	1864	279	6.0	12.6
	1984	279	5.6	12.5

Table 3 (cont.)

LAKEWOOD PROJECT - PUMP TEST HYDRO LAB DATA

TDD No.: R10-8301-08
Well No.: H-2

Date	Time Since Pumping Started (in min.)	Conductivity umhos	pH	t (°C)
2-11-83	2044	277	5.6	12.5
	2104	276	5.6	12.5
2-12-83	2164	277	5.5	12.4
	2224	276	5.8	12.6
	2284	275	5.5	12.4
	3244	275	5.5	12.6
	2404	274	5.9	12.4
	2464	274	6.0	12.6
	2570	272	6.0	12.6
	2652	272	6.1	12.6
	2718	272	5.7	12.6
	2780	270	5.6	12.6
	2835	270	5.5	12.6
	2890	269	5.5	12.6
	2958	269	5.6	12.6
	3064	268	5.9	12.7
	3139	267	5.8	12.6
	3266	266	6.0	12.5
	3401	265	6.0	12.5
	3476	265	6.0	12.4
	3590	263	6.0	12.4
2-13-83	3734	263	6.1	12.4
	3870	262	6.1	12.4
	4111	261	6.0	12.4
	4187	261	6.1	12.5
	4249	260	6.1	12.5
	4313	260	6.0	12.5

50 lbs. of salt dissolved in about 55 gallons of H_2O was discharged into well # 17 at 10 a.m. on 2-10-83. The pump test began at 1 p.m. on 2-10-83 and pH, conductivity, and temperature were monitored at the pumping well.

V. SAMPLING PROGRAM

5.1 Sampling Procedure

Each monitoring well was purged of at least five times the volume of water originally standing in the well. The rate of discharge was measured. Wells 1 to 10 were purged with a Robb Air Pump; Wells 11 to 25 were purged with a 2-inch Keck electric submersible pump. Pumps installed in H-1 and H-2 were run to purge the required amount. The amount of water discharged from each well is listed in Table 4. Each well was then allowed to recharge to its original level. Between wells the pumps and their discharge lines were submerged in potable water and allowed to run for two minutes to reduce the possiblity of cross contamination.

After recharge each well was bailed with a stainless steel bailer cleaned with distilled water, acetone and methanol successively and then dried in the air. The bailers were lowered into the well by monofilament line. The line was changed before each sampling.

Two 40-ml vials with teflon-lined septa were filled at each well. The samples were poured directly into the vials from the bailer to minimize evaporation. The bailer and the sampler's gloves were rinsed two times with the media to be analyzed. The gloves were changed between sampling to eliminate cross contamination. The outsides of the sample containers were rinsed with distilled water before the containers were placed in an ice chest. Temperature, pH and conductivity of the water were measured during sampling (Table 5).

TABLE 4
VOLUME OF WATER PURGED PRIOR TO SAMPLING
LAKEWOOD WATER DISTRICT

Well Number	Depth (ft)	Casing Diameter	Water Level	Water Standing In Well	Volume of Water In Well	Volume of Water to be Purged (U.S. gallons)
1	30	2	24.00	6.00	0.98	4
2	35	2	23.25	11.75	1.92	9
3	35	2	20.83	14.17	2.32	11
4	35	2	18.50	16.50	2.70	13
5	35	2	21.33	13.67	2.24	11
6	35	2	21.00	14.00	2.29	11
7	35	2	25.13	9.87	1.61	8
8	35	2	21.66	13.34	2.18	10
9	35	2	23.33	11.67	1.91	9
10	35	2	22.08	12.92	2.11	10
11A	85	2	23.58	61.42	10.04	50
11B	65	2	23.58	41.42	6.77	33
12	87	2	24.70	62.30	10.19	50
13A	231	2	18.33	212.67	34.77	173
13B	60	2	16.79	43.21	7.06	35
14	112	2	22.42	89.48	14.65	73
15A	110	2	24.08	85.92	14.05	70
15B	44	2	22.50	21.50	3.52	17
16A	110	2	24.71	84.29	55.14	275
16B	77	2	12.08	53.92	8.82	44
17A	120	2	26.23	93.77	14.33	76
17B	100	2	26.71	73.29	11.98	59
18	120	2	26.50	93.50	14.29	76
19A	106	2	27.79	78.21	12.79	63
19B	63	2	27.58	35.42	5.79	28
20A	103	2	21.42	81.58	12.34	66
20B	53	2	18.63	34.37	5.62	28
21	105	2	26.92	78.08	14.77	63
22	80	2	22.83	57.17	9.35	46
24A	120	2	23.75	96.25	14.73	78
24B	100	2	23.50	76.50	12.51	62
25	115	2	36.54	78.46	12.83	64
H-1	110	16	23.50	86.50	905.37	4,526
H-2	110	16	21.58	88.42	925.46	4,627

TABLE 5
SOME GROUNDWATER CHARACTERISTICS IN SAMPLED WELLS LAKEWOOD WATER DISTRICT

Date	Well Number	pH	Conductivity (micromhos)	Temperature (°C)
2-2-83	1	7.40	150	9
2-3-83	2	7.00	140	11
2-1-83	3	7.50	180	11
2-1-83	4	7.20	320	11
2-1-83	5	6.20	290	9
3-3-83	6	7.01	190	10
2-2-83	7	7.90	130	11
2-1-83	8	7.20	170	12
2-1-83	9	7.40	200	11
2-1-83	10	6.80	358	12
2-2-83	11A	8.40	170	10
2-2-83	11B	8.65	160	10
3-3-83	12	7.40	150	9
2-1-83	13A	7.50	290	13
3-3-83	13B	7.40	270	9
3-3-83	14	7.50	150	10
2-3-83	15A	8.30	270	12
2-3-83	15B	8.90	290	11
2-4-83	16A	7.50	350	11
2-4-83	16B	12.50	6000	12
2-7-83	17A	9.40	150	11
2-7-83	17B	9.00	200	11
3-8-83	18	6.50	250	12
3-8-83	19A	6.80	225	12
3-8-83	19B	8.50	550	12
2-4-83	20A	12.00	2400	16
2-4-83	20B	12.00	3100	11
2-7-83	21	10.12	180	12
3-3-83	22	9.70	170	11
2-2-83	24A	7.50	330	12
2-2-83	24B	7.80	340	10
2-7-83	25	7.25	210	11
2-2-83	H-1	7.20	340	12
2-2-83	H-2	7.10	320	12

5.2 Analytical Requirements

Samples were analyzed by the EPA Region 10 Laboratory for the following compounds: trichloroethylene, tetrachloroethylene, 1,2 (trans)-dichloroethene and 1,1,1-trichloroethane. The required detection limit was set at 1 ug/l.

5.2.1 STORET Assignment

The STORET group at the EPA Environmental Services Division was contacted prior to sampling. They assigned STORET numbers to the sampling locations.

5.3 Sample Packaging And Shipment

The sampling procedures were documented in a field log book.

Samples were accompanied by a Field Data Sheet, an Analyses Required Sheet, and a white copy of the Chain-of-Custody Record. The forms were sealed in a ziplock plastic bag.

Each sample container was labeled with the sample number. The ice chest carrying the samples was filled with ice and sealed with fiber tape before shipment in accordance with recommended EPA procedures (NEIC, 1980).

All sample containers were rolled in plain wrapping paper and packed in vermiculite inside a plastic bag. This in turn was packed in an outer bag containing ice. The bags were then placed inside an ice chest that was sealed with fiberglass tape and custody tape. Packing was in accordance with the requirements of the National Enforcement Investigations Center (NEIC, 1980).

5.3.1 Chain of Custody

All samples remained in the custody of the samplers until shipment to the EPA Region 10 Laboratory.

5.4 Quality Assurance Program

Two sets of blanks made up from organic-free distilled water were prepared by the EPA Region X Laboratory. The first set of blanks was taken into the field and then sent to the contract laboratory. The second set of blanks was taken into the field and transferred with the clean bailer into empty containers to determine whether contaminants were present in the bailer.

All samples were analyzed in accordance with EPA test procedures.

All analytical data obtained in this study has been reviewed by the Environmental Services Division for quality assurance acceptability.

5.5 Site Safety

As the respirable zone above the wells was not found to contain volatile organics and only trace levels (ppb) of volatile organics were detected in water samples collected from some of these wells, field personnel wore level D protective clothing (see Appendix B - site safety plan).

VI. RESULTS AND DISCUSSION

The investigation generated invaluable data concerning the geology, hydrology and chemistry of both the shallow and the deeper aquifers.

By sampling the groundwater at frequent intervals, the authors were able to delineate zones within the aquifer that were contaminated with the target compounds. The use of the Organic Vapor Analyzer allowed qualitative and semi-quantitative analyses to be made in the field, and also enabled the investigators to set the well screen opposite the most contaminated zone. Samples were checked with the OVA to determine which were to be sent to the laboratory for more detailed analyses. This helped to reduce the number of samples sent to the laboratory thereby saving time and analytical costs.

Such frequent sampling also allowed detailed geologic logging of each well. The complex nature of the geology is illustrated by the resultant cross section (figs. 14, 15). Rapid lateral variations made correlation between wells uncertain, and none are drawn.

Analytical results (Table 6) indicate that with the exception of well No. 1, none of the shallow wells is significantly contaminated by the target compounds analyzed. This confirms our previous conclusion (Wolf, Boateng, 1982, unpublished report) that the shallow aquifer is not the source of the contamination. Contaminent distribution in well No. 11 (Table 7) also confirms this.

Analysis of the pump test data shows that wells No. 16, 20 and 21 located north of H-2 respond quickly and have greater drawdown than other nearby wells (Appendix C).

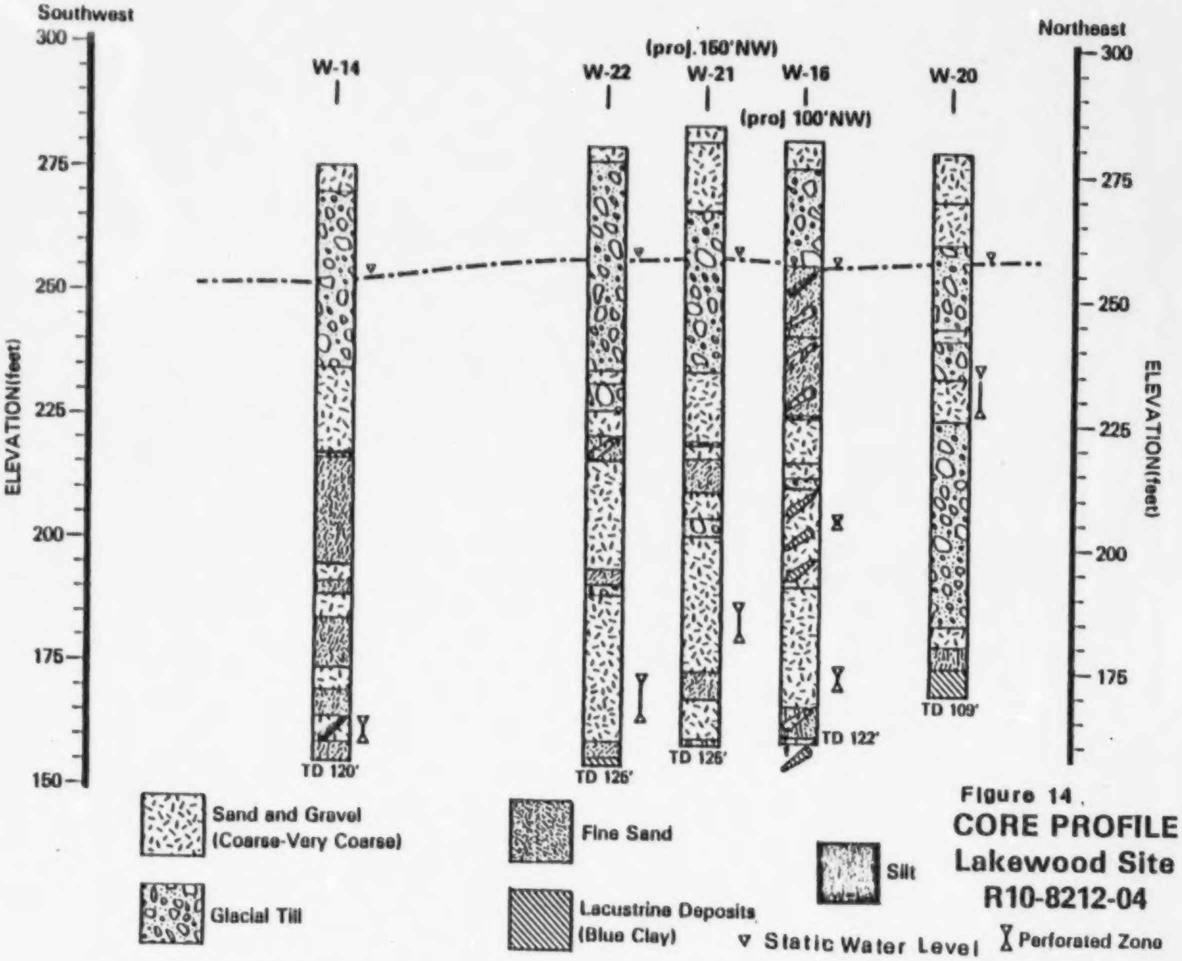
Southwest
Northeast
ELEVATION(feet)
300
275
250
225
200
175
150
W-14
W-22
(proj.160'NW)
W-21
W-16
(proj 100'NW)
W-20
TD 120'
TD 126'
TD 125'
TD 122'
TD 109'
Sand and Gravel (Coarse-Very Coarse)
Glacial Till
Fine Sand
Lacustrine Deposits (Blue Clay)
Silt
▿ Static Water Level
Perforated Zone

Figure 14

CORE PROFILE *A-A'*

Lakewood Site

R10-8212-04

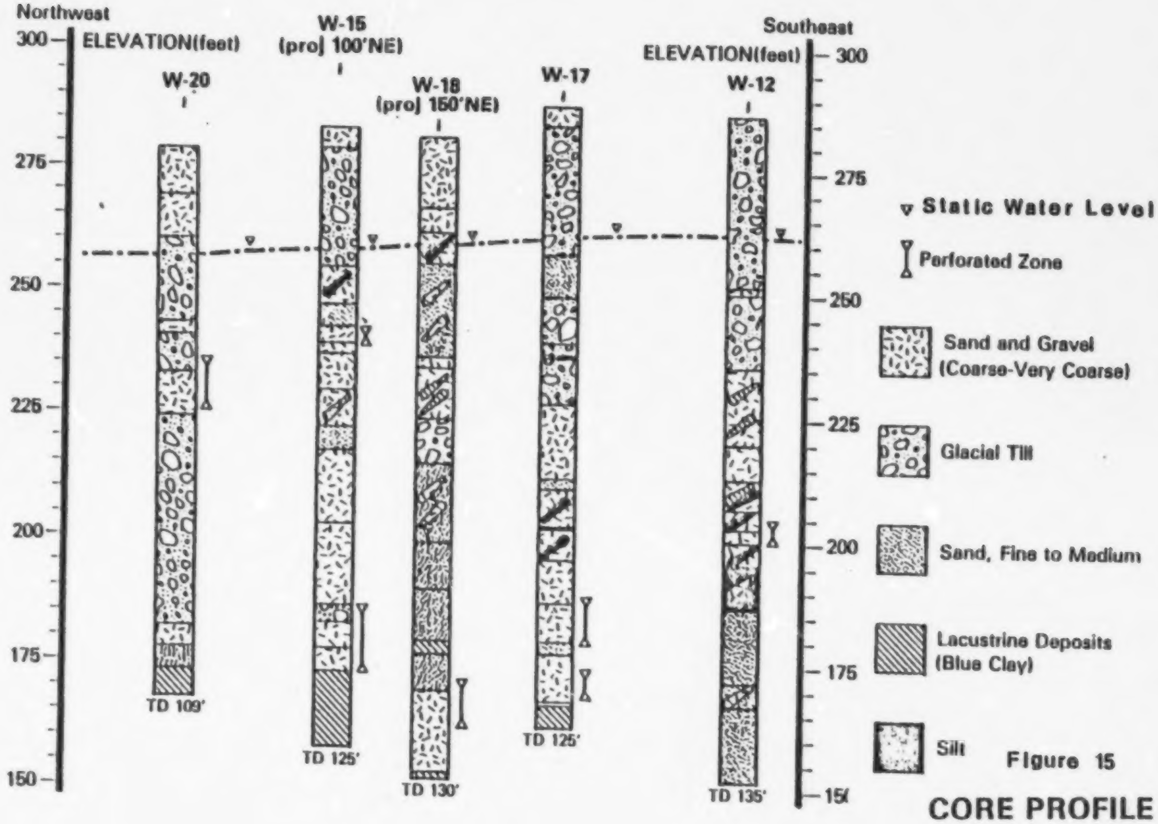
Northwest
ELEVATION(feet)
300
275
250
225
200
175
150
W-20
W-15
(proj 100'NE)
W-18
(proj 150'NE)
W-17
W-12
Southeast
ELEVATION(feet)
300
275
250
225
200
175
150
TD 109'
TD 125'
TD 130'
TD 125'
TD 135'
Static Water Level
Perforated Zone
Sand and Gravel (Coarse-Very Coarse)
Glacial Till
Sand, Fine to Medium
Lacustrine Deposits (Blue Clay)
Silt

Figure 15

CORE PROFILE *B-B'*
Lakewood Site
R10-8212-04

TABLE 6
CHEMICAL ANALYSES FOR VOLATILE ORGANIC COMPOUNDS
LAKEWOOD WATER DISTRICT

Date	Well Number	1,2(trans) dichloro-ethylene (ug/1)	Trichloro-ethylene (ug/1)	Tetrachloro-ethylene (ug/1)	1,1,1-Trichloro-ethane (ug/1)	Methylene chloride (ug/1)
02-02-83	1	1.5	1 M	1.6	---	---
02-03-83	2	---	---	---	---	---
02-01-83	3	---	---	---	---	---
01-31-83	4	1 M	---	1 M	1 M	---
01-31-83	5	---	---	---	1 M	---
02-03-83	6	1 M	---	1 M	---	---
02-02-83	7	---	---	---	---	---
02-01-83	8	1 M	---	1 M	---	---
02-01-83	9	---	---	---	---	---
01-31-83	10	---	---	1 M	1 M	---
02-02-83	11A	9.2	---	1 M	---	---
02-02-83	11B	5.6	1 M	1 M	---	---
02-03-83	12	---	---	---	---	111,400
02-01-83	13A	---	---	---	---	---
02-02-83	13B	---	1 M	---	---	---
02-03-83	14	---	---	---	---	6,670
02-03-83	15A	26	4.0	96	---	---
02-03-83	15B	100	4.7	60	---	---
02-04-83	16A	188	6.7	76	---	---
01-04-83	16B	14	1 M	4.0	---	---
02-07-83	17A	---	---	1 M	---	---
02-07-83	17B	---	---	---	---	---
02-23-83	18	---	---	1 M	---	---
02-23-83	19A	---	1 M	1 M	---	---
02-23-83	19B	---	---	1 M	1 M	---
02-04-83	20A	179	23	632	---	---
02-04-83	20B	485	43	362	---	---
02-07-83	21	41	1.9	19	---	---
02-03-83	22	---	---	---	---	---
02-03-83	24A	202	22	522	---	---
02-02-83	24B	224	25	517	---	---
02-23-83	25	---	---	---	---	---
02-02-83	H-1	268	26	417	---	---
02-02-83	H-2	220	25	345	---	---

1 M = Above the sensitivity but less than the level of quantification (Not Quantifiable).

--- = Below the detection level (Not Detected).

TABLE 7
WELL NUMBER 11
CONTAMINANT DISTRIBUTION
LAKEWOOD WATER DISTRICT

Sample Depth (feet)*	Trichloro-ethylene (ug/l)	Tetrachloro-ethylene (ug/l)	1,2-transdichloro-ethylene (ug/l)
60	not detected	1.4	4.5
65	not detected	not detected	not detected
70	not detected	not detected	not detected
75	8.6	185	65
80	6.8	150	76
85	6.4	185	67
90	42	1270	225

*Samples obtained at 27', 31', 46', 50' and 55' showed no contamination on the OVA-128, therefore, no sample was sent to the EPA Laboratory.

Chemical time series data (Table 2) shows initial rapid increase in trichloroethylene, tetrachloroethylene and 1,2-(trans)dichloroethylene, followed by a steady decline. The rapid increase suggested a nearby source. The high levels of those compounds found in wells No. 16 and 20, (Table 8) coupled with the high pH, conductivity and elevated temperature (Table 5) suggested that the source of the contamination in the production wells H-1 and H-2 is in the immediate vicinity of well No. 20. The fact that the major source of contamination lies north of H-1 and H-2 explains why, when both are pumping, H-2, which is north and west of H-1, shows higher levels of contamination.

Wells Nos. 12, 13 and 14 were drilled to intercept flow between alleged disposal sites on McChord Airforce Base and the production wells. None showed contamination while they were drilled, so they were completed in what appeared to be zones of relatively high permeability. Wells Nos. 12 and 14 were completed in the same aquifer as H-1 and H-2 and Well 13 in the lower aquifer tapped by wells on McChord Air Force Base.

Very high levels of methylene chloride (up to 100 ppm) were found in wells Nos. 12 and 14 during the February 1983 sampling. This compound was not detected in the pumping well, despite drawdowns in the monitoring wells indicating at least some hydraulic connection with H-2. It is probable that the pump test was not sufficiently prolonged. It may also be that these wells lie outside the area from which H-2 draws water. The water level fluctuations of well No. 13 probably reflect pumping of the wells on the McChord Air Force Base.

TABLE 8
RESULTS OF CHEMICAL ANALYSES FOR RESAMPLED WELLS AT LAKEWOOD WATER DISTRICT

Date	Well Number	1,2(trans)-dichloro-ethylene (ug/1)	Trichloro-ethylene (ug/1)	Tetrachloro-ethylene (ug/1)	1,1,1-Trichloro-ethane (ug/1)
3-9-83	16A	180	4.7	44	---
3-9-83	16B	9.7	1 M	3.2	---
3-8-83	18	---	1 M	---	---
3-8-83	19A	---	1 M	---	---
3-8-83	19B	---	---	---	---
3-7-83	20A	40	5.7	195	---
3-7-83	20B	837	98	2590	---
3-8-83	24A	175	20	518	---
3-8-83	24B	110	14	326	---
3-8-83	25	---	---	---	---

1 M = Above the sensitivity but less than the level of quantification (Not Quantifiable).

--- = Below the detection level (Not Detected).

Drawdowns were recorded in the shallow wells. This indicates that there is interconnection between the shallow aquifer and the deeper aquifer. This confirms our previous investigation (Wolf, Boateng, 1982, unpublished report).

VII. CONCLUSIONS AND RECOMMENDATIONS

The use of field instrumentation and frequent sampling during monitoring well drilling have proved to be an indispensible tool for locating low level contamination with volatile organics. In complex geology it is essential to delineate zones of contamination and to install well screens opposite those zones only. This prevents dilution and possible non-detection of contamination. Keeping an open mind and exploring several alternative hypotheses has also proven to be necessary. It has been found that where lateral variations of lithology in an aquifer are high, even relatively closely spaced monitoring wells do not allow confidence in postulating hydraulic connections, and a long-duration aquifer test monitoring as many wells as possible is essential.

It is concluded that at least two sources of groundwater contamination occur in the study area. One source was identified as a laundry and dry cleaner located in the immediate vicinity of monitoring well No. 20. This source is affecting the groundwater quality of Lakewood Water District Production Wells H-1 and H-2. A second source, or more than one, appears to lie somewhere to the southeast of the production wells and is creating the high levels of methylene chloride that are found in wells Nos. 12 and 14.

It is recommended that the contaminated discharge from the laundry and dry cleaners near well No. 20 be eliminated.

o that after the sources of contamination have been eliminated, wells H-1 and H-2 be run at intervals and sampled to determine when acceptable levels of water purity are achieved,

- that if acceptable levels are not achieved within a reasonable time then cost/benefit studies of treatment or the use of alterative sources be done.

- That a follow-up study be done to confirm and delineate the methylene chloride contamination.

BIBLIOGRAPHY

EPA, 1977, Procedures Manual for Groundwater Monitoring at Solid Waste Disposal Facilities: EPA/530/SW-611.

Freeze, Allen R., J.A. Cherry, 1979; Groundwater, Prentice Hall, N.J.

Griffin, W.D.; J.E. Sceva, H.A. Swenson, and M.J. Mundorff, 1962: Water Resources of the Tacoma Area, WA. USGS Water Supply Paper 1499B. U.S. GPO, Washington, D.C.

Littler, J.D., J.T. Aden, A.F. Johnson, 1980-1981, Survey of Groundwater and Surface Water Quality for the Chambers Creek/ Clover Creek Drainage Basin, Pierce County, Washington State Dept. of Social and Health Services, Health Services Division, Water Supply and Waste Section, LD-11, Olympia, WA.

Miller, J.F., R.H. Frederic, R.J. Tracey, 1973, Precipitation Frequency Atlas of the Western United States: Vol. IX, Washington U.S. Dept. of Commerce, NOAA, National Weather Service, Silver Springs, MD.

National Enforcement Investigations Center (NEIC), 1980, Enforcement Considerations for Evaluation of Uncontrolled Hazardous Waste Disposal Sites by Contractors: EPA, Denver, CO.

Sceva, J.E., 1957: Geology and Groundwater Resources of Kitsap County Washington. USGS Water Supply Paper 1413.

Sceva, J.E., 1983, personal communication: Environmental Protection Agency, Seattle, WA.

U.S. Dept. of Commerce (DOC), 1968, Climatic Atlas of the United States, Environmental Services Administration, Environmental Data Service, National Climatic Center, Asheville, NC.

U.S. Dept. of Commerce (DOC), 1981, Local Climatological Data, 1980, Seattle-Tacoma Airport. NOAA Environmental Data and Information Service, National Climatic Center, Asheville, NC.

U.S. Geological Survey (USGS), 1959, (photo rev. 1973) Steilacoom Quadrangle, Steilacoom, WA, 7.5 Minute Series (topographic), Scale 1:24,000.

Walters, K.L., G.E. Kimmel, 1968: Groundwater Occurence and Stratigraphy of Unconsolidated Deposits, Central Pierce County, WA. Water Supply Bulletin No. 22. State of Washington Dept. of Water Resources in Cooperation with the USGS.

Wolf, F.G., K. Boateng, 1981: Report of the Preliminary Groundwater Contamination Investigation, Lakewood, WA. U.S. EPA Region 10, Seattle, WA.

APPENDIX A - WELL LOGS

LAKEWOOD WELL LOGS

Materials Encountered	Thickness (feet)	Depth (feet)
Monitoring Well No.1. Date Completed: 10-12-81		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Sand and gravels with cobbles, loose.	14	14
Generally fine to medium gravels with cobbles.	9	23
Generally large cobbles, loose.	1	24
Small to medium cobbles.	6	30
Casing: 2-inch steel, set to 30 feet; perforated from 15-30 feet.		
Elevation of top of casing 281.2 feet.		
Static water level 24.00 feet.		
Monitoring Well No.2. Date Completed: 10-14-81		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Coarse sand and gravels with few cobbles, loose.	15	15
Mainly coarse gravels.	3	18
Fine to medium gravels	3	21
Coarse gravels with few large cobbles	5	26
Small to medium gravels, loose	9	35
Casing: 2-inch steel, set to 30 feet; perforated from 15-35 feet.		
Elevation of top of casing 282.5 feet.		
Static water level 23.25 feet.		

LAKEWOOD WELL LOGS

Materials Encountered	Thickness (feet)	Depth (feet)
Monitoring Well No.3. Date Completed: 10-14-81		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Generally fine to medium sand and gravels, loose.	25	25
Medium to coarse gravels.	10	35
Casing: 2-inch steel, set to 35 feet; perforated from 25-35 feet.		
Elevation of top of casing 281.0 feet.		
Static water level: 20.83 feet.		

Materials Encountered	Thickness (feet)	Depth (feet)
Monitoring Well No.4. Date Completed: 10-15-81.		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Fine to medium sand and gravels.	13	13
Medium to coarse gravels with cobbles, loose.	15	28
Generally coarse gravels with few cobbles.	7	35
Casing: 2-inch steel, set to 35 feet; perforated from 25-35 feet.		
Elevation of top of casing 278.7 feet.		
Static water level: 18.50 feet.		

LAKEWOOD WELL LOGS

Materials Encountered	Thickness (feet)	Depth (feet)
Monitoring Well No.5. Date Completed: 10-20-81		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Sand and gravels, loose	4	4
Generally fine to medium gravels, loose.	4	8
Fine gravels with occasional zones of cobbles.	9	17
Medium to coarse gravels with few boulders, loose.	11	28
Fine sand and gravels with few cobbles.	7	35

Casing: 2-inch steel, set to 35 feet;
perforated from 25-35 feet.

Elevation of top of casing 279.5 feet.

Static water level: 21.33 feet.

Monitoring Well No.6. Date Completed: 10-21-81		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Sandy clay with gravels (fill)	5	5
Sand and gravels, loose.	4	9
Medium to coarse sand and gravels with few cobbles.	1	10
Coarse gravels and cobbles.	25	35

Casing: 2-inch steel, set to 35 feet;
perforated from 25-35 feet.

Elevation of top of casing 280.5 feet.

Static Water level: 21.00 feet.

LAKEWOOD WELL LOGS

Materials Encountered	Thickness (feet)	Depth (feet)
Monitoring Well No.7. Date Completed: 10-21-81		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Sand and gravels (fill).	3	3
Sand and gravels with cobbles.	3	6
Generally fine to coarse gravels	12	18
Medium to coarse gravels with occasional cobbles.	11	29
Sand and gravels with clay lenses.	6	35

Casing: 2-inch steel set at 35 feet;
perforated from 25-35 feet.

Elevation of top of casing 281.9 feet.

Static water level: 25.13 feet.

Materials Encountered	Thickness (feet)	Depth (feet)
Monitoring Well No.8. Date Completed: 10-22-81		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Top soil--sandy clay.	2	2
Medium to coarse sand and gravels with few cobbles	5	7
Generally coarse gravels.	19	26
Sand and gravels with few cobbles.	2	28
Coarse gravels with cobbles.	7	35

Casing: 2-inch steel, set to 35 feet;
perforated from 25-35 feet.

Elevation of top of casing 280.1 feet.

Static water level: 21.66 feet.

LAKEWOOD WELL LOGS

Materials Encountered	Thickness (feet)	Depth (feet)
Monitoring Well No.9. Date Completed: 10-22-81		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Top soil, sandy clay with few gravels.	2	2
Coarse gravels.	9	11
Fine to medium gravels with few cobbles.	4	15
Generally coarse gravels with cobbles, clean, loose.	8	23
Cobbles, loose.	12	35

Casing: 2-inch steel, set to 35 feet;
perforated from 25-35 feet.

Elevation of top of casing 282.5 feet.

Static water level: 23.33 feet.

Monitoring Well No.10. Date Completed: 10-23-81

VASHON DRIFT:

Steilacoom gravels (Recessional Outwash):

Materials Encountered	Thickness (feet)	Depth (feet)
Gravels.	4	4
Generally medium to coarse sand.	2	6
Sand and gravels.	9	15
Medium to coarse gravels with few cobbles, loose.	12	27
Coarse sand and gravels with cobbles.	7	34
Medium to coarse gravels.	1	35

Casing: 2-inch steel, set to 35 feet;
perforated from 25-35 feet.

Elevation of top of casing 283.3 feet.

Static water level 22.08 feet.

LAKEWOOD WELL LOGS

Materials Encountered	Thickness (feet)	Depth (feet)
Monitoring Well No. 11. Date Completed: 3-15-82		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Coarse sand and gravels with cobbles.	21	21
Till:		
Glacial till, cemented.	17	38
Advance Outwash:		
Generally gravels with cobbles, loose. Encountered water at 36 feet.	11	49
Same as above but more cemented. Amount of water decreases with increase in cementation.	10	59
Coarse sand and gravels with cobbles, loose.	35	94

Casings: 2-level well construction.
2-inch steel casing set at 90 feet;
perforated from 75-85 feet (deeper level).
2-inch PVC steel casing set at 65 feet;
perforated from 60-65 feet (shallow level).

Elevation of top of casing: 282.3 feet.

Static Water level: 23.58 feet (deeper level)
23.58 feet (shallow level)

LAKEWOOD WELL LOGS

Materials Encountered	Thickness (feet)	Depth (feet)
Monitoring Well No.12. Date Completed: 6-3-82.		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Sand and gravel with cobbles.	1	1
Till:		
Glacial till, highly cemented (looks like concrete). Water at 35 feet.	34	35
Medium to coarse sand and gravels, loose.	2	37
Glacial till, cemented.	3	40
Advance Outwash:		
Coarse sand and gravels with occassional clay lenses.	14	54
Coarse sand and gravels generally loose.	16	70
Same as above with occassional silt and clay lenses.	7	77
Generally fine sand with few coarse gravels. Silt lenses do occur.	6	83
Coarse sand and gravels, loose.	4	87
Generally medium sand and gravels with few cobbles; silt lenses do occur.	4	91
Silt with some gravels.	9	100
Fine sand.	15	115
Fine sand with few gravels.	5	120
Colvos sands: ?		
Fine sand	15	135

Casing: 2-inch PVC, set to 87 feet;
perforated from 82-87 feet.

Elevation of top of casing 287.6 feet.

Static water level 24.71 feet.

LAKEWOOD WELL LOGS

Materials Encountered	Thickness (feet)	Depth (feet)
Monitoring Well No.13A. Date Completed: 8-12-82		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Sand and gravels with cobbles, loose.	2	2
Generally sand with some clay.	8	10
Same as above, but slightly cemented.	15	25
Fine to medium sand, encountered water at 25'	6	31
Till:		
Glacial till, highly cemented, looks like concrete.	22	53
Gravels, loose.	5	58
Glacial till, cemented.	12	70
Advance Outwash:		
Fine sand with gravels, gravel content decreases with depth.	18	88
Fine sand with silt lenses, silt content increases with depth.	36	124
Colvos Sands: ?		
Silt, bluish with occasional clay seams.	7	131
Blue clay, solft, slightly silty.	11	142
Silt.	11	153
Fine sand, loose.	11	164
Blue clay, rather silty.	17	181
Sand and gravels, with few cobbles, slightly cemented.	13	194
Silty clay with gravels, slightly cemented	8	202
Fine sand, loose.	6	208
Coarse sand and gravels with silt lenses.	4	212
Fine to medium sand with silt lenses.	9	221
Coarse sand and gravels with few cobbles, slightly cemented.	10	231
Same as above but more cemented.	9	240
Silt.	20	260

Casing: 2-inch PVC set at 231 feet;
perforated from 221-231.

Elevation of top of casing 284.2 feet.

Static water level: 18.33 feet.

LAKEWOOD WELL LOGS

Materials Encountered	Thickness (feet)	Depth (feet)
Monitoring Well No.14. Date Completed: 08-06-82		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash): ?		
Coarse sand and gravels with cobbles, loose.	5	5
Till:		
Glacial till, highly cemented, (looks like concrete).	36	41
Advance Outwash:		
Coarse sand and gravels with few cobbles, loose. Encountered water at 41 feet.	17	58
Coarse sand and gravels, cemented.	1	59
Same as above but loose.	1	60
Fine sand.	18	78
Medium to coarse sand.	6	84
Fine sand with cobbles.	2	86
Medium to coarse sand and gravels with lenses.	5	91
Colvos Sands: ?		
Fine sand.	11	102
Generally gravels.	4	106
Fine sand.	6	112
Sand and gravels with silt lenses, loose.	5	117
Fine sand.	3	120
Casing: 2-inch PVC, set at 117; perforated from 112-117.		
Elevation of top of casing 276.3 feet.		
Static water level: 22.42 feet.		

LAKEWOOD WELL LOGS

Materials Encountered	Thickness (feet)	Depth (feet)
Monitoring Well No.15. Date Completed: 08-24-82		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Coarse sand and gravels, loose.	4	4
Till:		
Glacial till, highly cemented.	23	27
Advance Outwash:		
Coarse sand and gravels with some silt, slightly cemented.	8	35
Fine sand.	5	40
Gravels with few cobbles. Encountered water at 40 feet.	4	44
Coarse sand.	2	46
Coarse gravels with cobbles, slightly cemented. Amount of water decreased with depth until the water disappears between 50-53 feet.	7	53
Generally coarse sand and gravels with occasional layers of fine sand.	7	60
Fine to medium sand.	5	65
Gravels and cobbles, cemented.	15	80
Same as above, but water bearing, more cemented.	16	96
Glacial till, highly cemented?	4	100
Generally coarse sand and gravels.	5	105
Gravels with cobbles, slightly cemented.	5	110
Colvos Sands:		
Blue clay, soft, rather silty.	15	125

Casings: 2-level well construction.
2-inch PVC set at 110 feet;
perforated from 100-110 (deeper level);
2-inch PVC set at 44 feet;
perforated from 40-44 feet (shallow level).

Elevation of top of casing 283.3 feet.

Static water level: 24.92 feet (deeper well);
22.50 feet (shallow well).

LAKEWOOD WELL LOGS

Materials Encountered	Thickness (feet)	Depth (feet)
Monitoring Well No.16. Date Completed:09-08-82		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Sand and gravels with pieces of wood (fill)	6	6
Till:		
Glacial till, highly cemented, (looks like concrete).	19	25
Advance Outwash:		
Fine sand, rather silty, cemented. Few gravels do occur.	14	39
Fine sand and gravels, gravel content decreases with depth.	16	55
Generally fine sand with few coarse gravels. Encountered water at 55 feet.	1	56
Medium to coarse sand and gravels.	9	65
Same as above but cemented. Amount of water decreases with depth.	3	68
Glacial till, cemented.	2	70
Coarse sand and gravels with clay lenses, cemented.	20	90
Coarse sand and gravels with cobbles, loose, water bearing.	24	114
Fine to medium sand with few gravels, cemented.	7	121
Coarse sand and gravels with some clay, cemented.	1	122

Casings: 2-level well construction.
4-inch PVC, set at 110 feet;
perforated from 105 to 110 feet (deeper level).
2-inch PVC, set at 77 feet;
perforated from 75-77 feet (shallow level).

Elevation of top of casing 282.2 feet.

Static water level: 25.71 feet (deeper level);
23.08 feet (shallow level).

LAKEWOOD WELL LOGS

Materials Encountered	Thickness (feet)	Depth (feet)
Monitoring Well No.17. Date Completed: 09-22-82		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Coarse sand and gravels, with few cobbles, loose.	4	4
Till and Gravels:		
Glacial till, highly cemented, degree of cementation decreases with depth.	26	30
Fine sand, rather silty.	8	38
Glacial till, highly cemented.	12	50
Medium to coarse sand with few gravels, loose. Encountered water at 50 feet.	1	51
Glacial till, cemented.	9	60
Advance Outwash:		
Generally coarse sand and gravels with some cobbles, loose.	15	75
Fine sand, loose.	2	77
Coarse sand with silt lenses, slightly cemented.	7	84
Generally fine sand.	1	85
Coarse sand with some silt.	7	92
Fine to medium sand and gravel, loose.	8	100
Same as above but slightly cemented.	7	107
Generally fine sand.	4	111
Medium to coarse sand and gravel.	2	113
Same as above. Amount of water increases with depth.	7	120
Fine Sand with cobbles, loose. Cobbles are generally rounded with smooth surfaces.	1	121
Colvos sands: ?		
Blue clay, rather silty.	4	125

Casings: 2-level well construction.
2-inch PVC, set at 120 feet;
perforated from 116-120 feet (deeper level).
2-inch PVC set at 100 feet;
perforated from 90-100 feet (shallow level).

Elevation of top of casing 288.3 feet.

Static water level: 26.63 feet (deeper level);
26.71 feet (shallow level).

LAKEWOOD WELL LOGS

Materials Encountered	Thickness (feet)	Depth (feet)
Monitoring Well No.18. Date Completed:10-02-82		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Coarse sand and gravels, with few cobbles, loose.	15	15
Same as above with peat.	5	20
Coarse sand and gravels with some silt, slightly cemented.	6	26
Generally fine sand with few cobbles.	19	45
Coarse gravels and cobbles, loose. Encountered water at 46 feet.	3	48
Coarse sand and gravels with some clay, slightly cemented.	10	58
Till:		
Glacial till, highly cemented, (looks like concrete).	8	66
Advance Outwash:		
Fine to medium sand and gravels with few cobbles, loose.	17	83
Fine to medium sand, loose.	8	91
Generally medium sand. Amount of water appears to decrease with depth.	12	103
Sandy clay.	2	105
Medium sand.	8	113
Gravels, cemented. Degree of cementation increases with depth.	16	129
Colvos Sands: ?		
Blue clay, fairly plastic.	1	130

Casings: 2-inch PVC, set at 120 feet;
perforated from 110-120 feet.

Elevation of top of casing 282.4 feet.

Static water level: 22.5 feet.

LAKEWOOD WELL LOGS

Materials Encountered	Thickness (feet)	Depth (feet)
Monitoring Well No.19. Date Completed: 10-28-82		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Sand and gravels, loose.	3	3
Medium to fine sand with few gravels.	8	11
Till and gravels:		
Glacial till, highly cemented, (looks like concrete).	3	14
Gravels, with few cobbles, loose.	1	15
Glacial till, cemented.	44	59
Coarse sand and gravel with cobbles, loose. Encountered water at 59 feet.	4	63
Glacial till highly cemented. (looks like concrete).	5	68
Advance Outwash:		
Fine to medium sand.	6	74
Coarse sand and gravels.	10	84
Fine to medium sand and gravels. Grain size increases with depth.	22	106
Fine sand with few cobbles.	6	112
Fine sand with silt lenses. Amount of water decreases with depth.	10	122
Colvos Sands:		
Blue clay, rather sandy.	3	125

Casings: 2-level well construction.
2-inch PVC set at 106 feet;
perforated from 96-106 feet (deeper level).
2-inch PVC set at 63 feet;
perforated from 59-63 feet (shallow level).

Elevation of top of casing 289.9 feet.

Static water level: 27.79 feet (deeper level);
27.58 feet (shallow level).

LAKEWOOD WELL LOGS

Materials Encountered	Thickness (feet)	Depth (feet)
Monitoring Well No.20. Date Completed: 11-08-82		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Coarse sand and gravels, loose.	10	10
Same as above, with peat.	8	18
Till and gravels:		
Glacial till, highly cemented.	17	35
Medium to coarse sand and gravels.	2	37
Glacial till, highly cemented.	8	45
Medium to coarse sand and gravels, slightly cemented. Encountered water at 46 feet.	8	53
Glacial till, cemented.	31	84
Advance Outwash:		
Coarse sand and gravels, loose.	5	89
Fine to medium sand, loose. Grain size decreases with depth.	14	103
Colvos sands: ?		
Clay, bluish, fairly plastic.	6	109

Casings: 2-level well construction:
2-inch PVC set at 103 feet;
perforated from 93-103 feet (deeper level).
2-inch PVC set at 53 feet;
perforated from 43-53 feet (shallow level).

Elevation of top of casing 279.8 feet.

Static water level: 21.42 feet (deeper level);
18.63 feet (shallow level).

LAKEWOOD WELL LOGS

Materials Encountered	Thickness (feet)	Depth (feet)
Monitoring Well No.21. Date Completed:11-22-82		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Coarse sand and gravels with cobbles, loose.	3	3
Same as above with peat	14	17
Till and gravels:		
Glacial till, highly cemented.	32	49
Coarse sand and gravels. Encountered water at 50 feet.	14	63
Glacial till, cemented.	1	64
Medium to coarse sand and gravels, loose.	3	67
Fine sand, loose.	6	73
Medium to coarse sand and gravels.	5	78
Glacial till, cemented.	4	82
Coarse sand and gravels, loose.	28	110
Generally fine sand, loose.	6	116
Generally gravels, highly cemented. Amount of water decreases with depth.	7	123
Glacial till, cemented.	2	125

Casing: 2-inch PVC set at 105 feet;
perforated from 90-105 feet.

Elevation of top of casing 284.2 feet.

Static water level: 26.92 feet.

LAKEWOOD WELL LOGS

Materials Encountered	Thickness (feet)	Depth (feet)
Monitoring Well No.22. Date Completed: 12-09-82		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Coarse sand and gravels with cobbles, loose.	3	3
Glacial till, highly cemented.	42	45
Coarse sand and gravels with few cobbles, loose. Encountered water at 45 feet.	3	48
Till and gravels:		
Glacial till, cemented.	5	53
Generally gravels.	5	58
Fine to medium sand with few gravels.	5	63
Generally coarse sand and gravels with few cobbles, loose. Amount of water increases with depth.	22	85
Fine sand, slightly cemented.	3	88
Glacial till, cemented.	2	90
Advance Outwash: ?		
Coarse sand and gravels, loose	30	120
Fine sand, slightly cemented.	3	123
Colvos Sands: ?		
Blue clay, rather sandy with few cobbles.	2	125
Casing: 2-inch PVC set at 80 feet; perforated from 80-90 feet.		
Elevation of top of casing 280.9 feet.		
Static water level: 22.83 feet.		

LAKEWOOD WELL LOGS

Materials Encountered	Thickness (feet)	Depth (feet)
Monitoring Well No.23. Date Abandoned:12-10-82		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Top soil, sandy clay with gravels.	2	2
Medium to coarse sand and gravels, generally loose.	21	23
Till:		
Glacial till	16	39
Boring was abandoned at 39 feet. Property owner withdrew permission of access.		

LAKEWOOD WELL LOGS

Materials Encountered	Thickness (feet)	Depth (feet)
Monitoring Well No.24. Date Completed: 01-04-83		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Coarse sand and gravels with cobbles.	20	20
Till:		
Glacial till, cemented.	17	37
Advance Outwash:		
Gravels with cobbles, loose. Encountered water at 37 feet.	10	47
Same as above but cemented. Amount of water decreases with increase in cementation.	5	52
Coarse sand and gravels with cobbles, loose.	13	65
Same as above but slightly cemented.	40	105
Coarse sand and gravels, loose. Amount of water increases with depth.	5	110
Generally silt with some sand and gravels.	10	120
Colvos Sands: ?		
Clay, bluish, fairly plastic.	2	122

Casings: 2-level well construction.
2-inch PVC set at 120 feet;
perforated from 115-120 feet (deeper level).
2-inch PVC set at 100 feet;
perforated from 87-100 feet (shallow level).

Elevation of top of casing 282.0 feet.

Static water level: 23.75 feet (deeper level);
23.50 feet (shallow level).

LAKEWOOD WELL LOGS

Materials Encountered	Thickness (feet)	Depth (feet)
Monitoring Well No.25. Date Completed: 01-18-83		
VASHON DRIFT:		
Steilacoom gravels (Recessional Outwash):		
Top soil, sandy clay.	2	2
Generally gravels with cobbles, loose.	1	3
Till and gravels:		
Glacial till, highly cemented.	44	47
Coarse sand and gravels cemented. Encountered water at 47 feet.	4	51
Glacial till, cemented.	9	60
Advance Outwash:		
Coarse sand and gravels, loose.	15	75
Fine to medium sand and gravels.	10	85
Same as above but slightly compacted.	11	96
Medium to coarse sand and gravels. Amount of water increases with depth.	19	115.
Colvos Sands: ?		
Clay, bluish, fairly plastic.	3	118

Casing: 2-inch PVC set at 115 feet;
perforated from 105-115 feet.

Elevation of top of casing: Not surveyed in.

Static water level: 21.58 feet.

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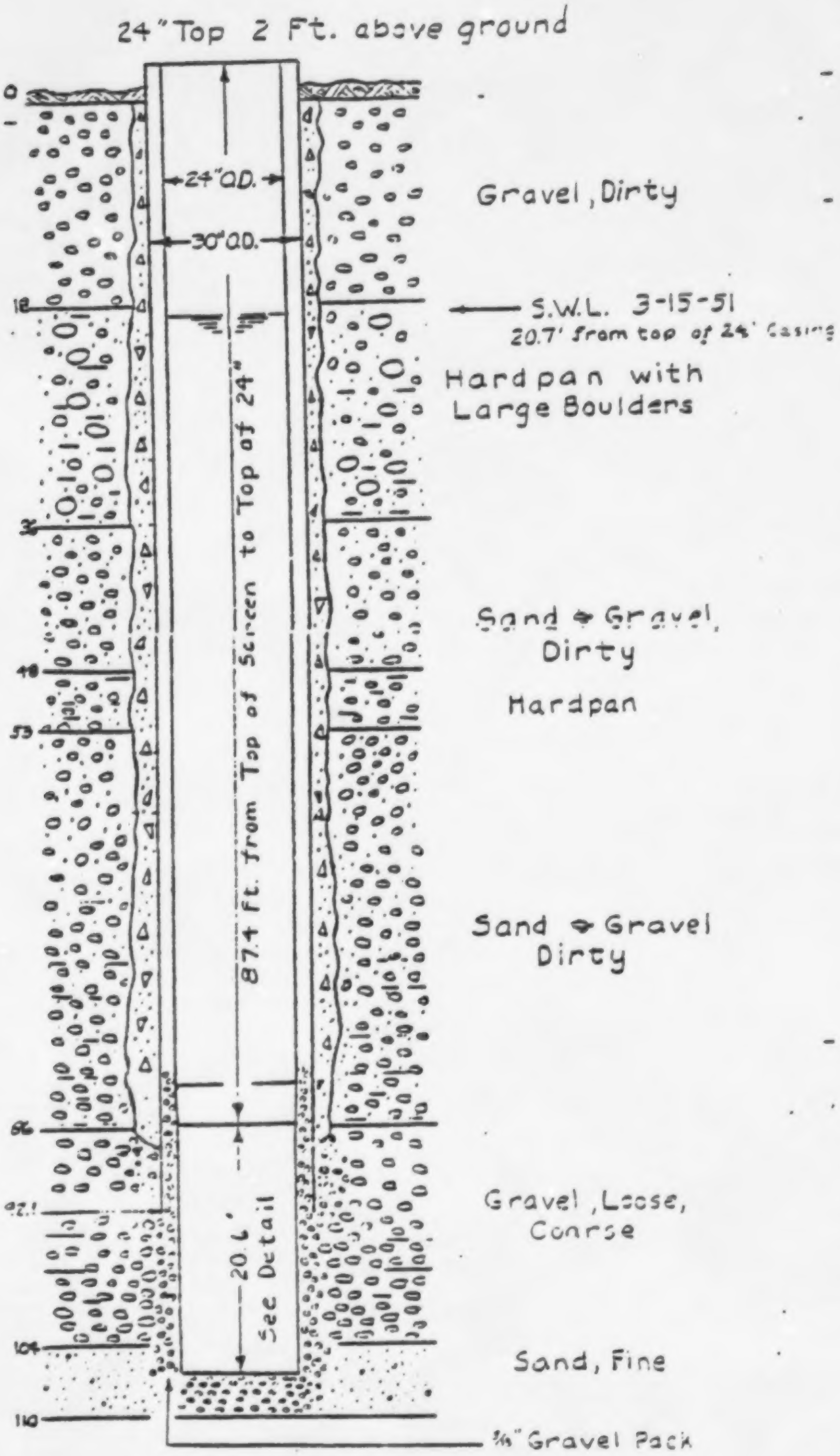
1. Water levels were measured from the top of the steel casing.

2. Elevations are based on Mean Sea Level (MSL).


24"Top 2 Ft. above ground
0
18
38
48
53
86
92.1
104
110
24"O.D.
30"O.D.
87.4 Ft. from Top of Screen to Top of 24"
20.6'
See Detail
Gravel, Dirty
S.W.L. 3-15-51
20.7' from top of 24' Casing
Hardpan with Large Boulders
Sand & Gravel, Dirty
Hardpan
Sand & Gravel Dirty
Gravel, Loose, Coarse
Sand, Fine
¾" Gravel Pack

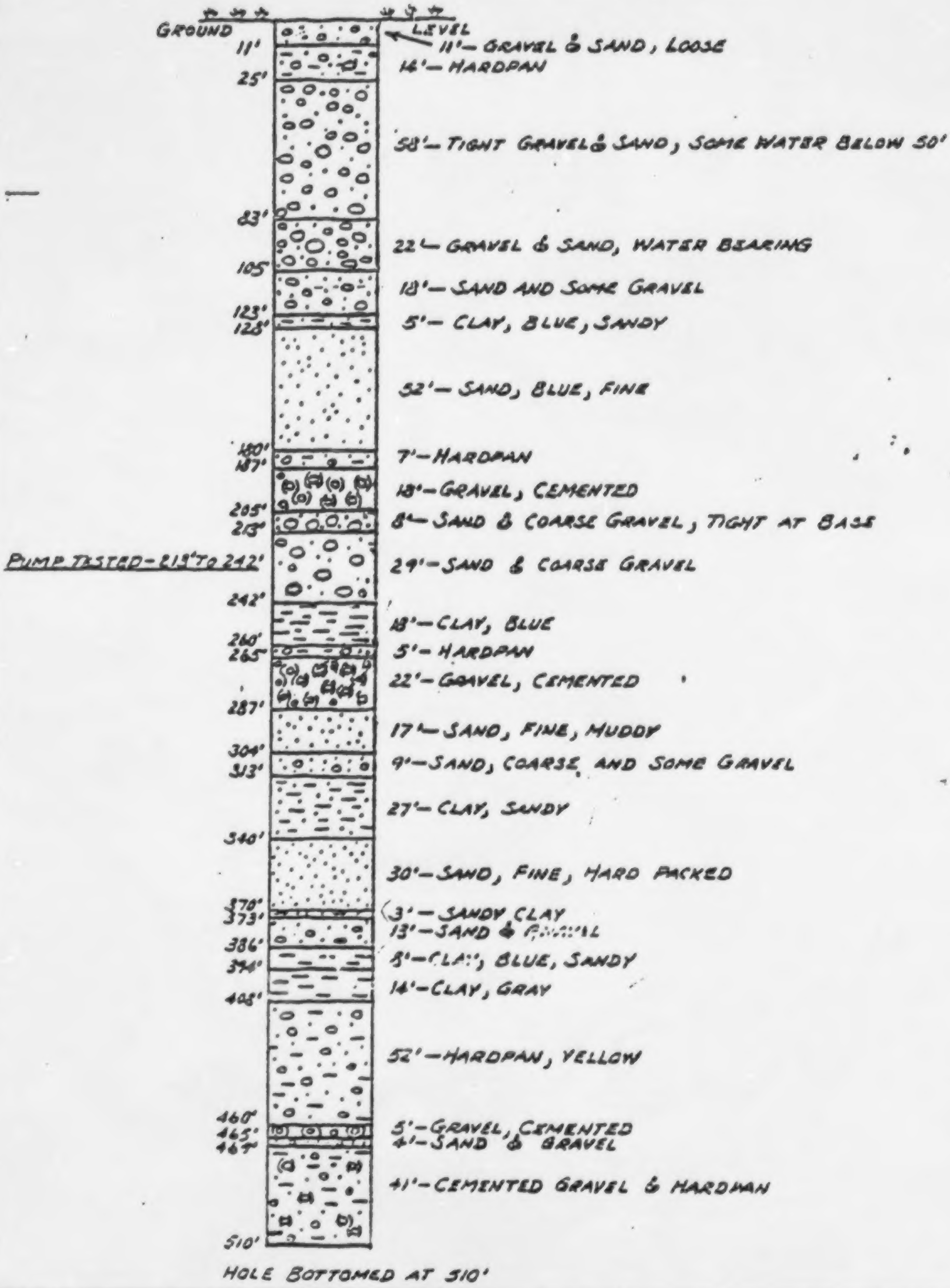
WELL DATA

30" & 24" Casing ⅜" Thick

Δ Cement, Gravel & Sand Grout Backfill

Gravel Backfill from 106' to 110' Below Screen

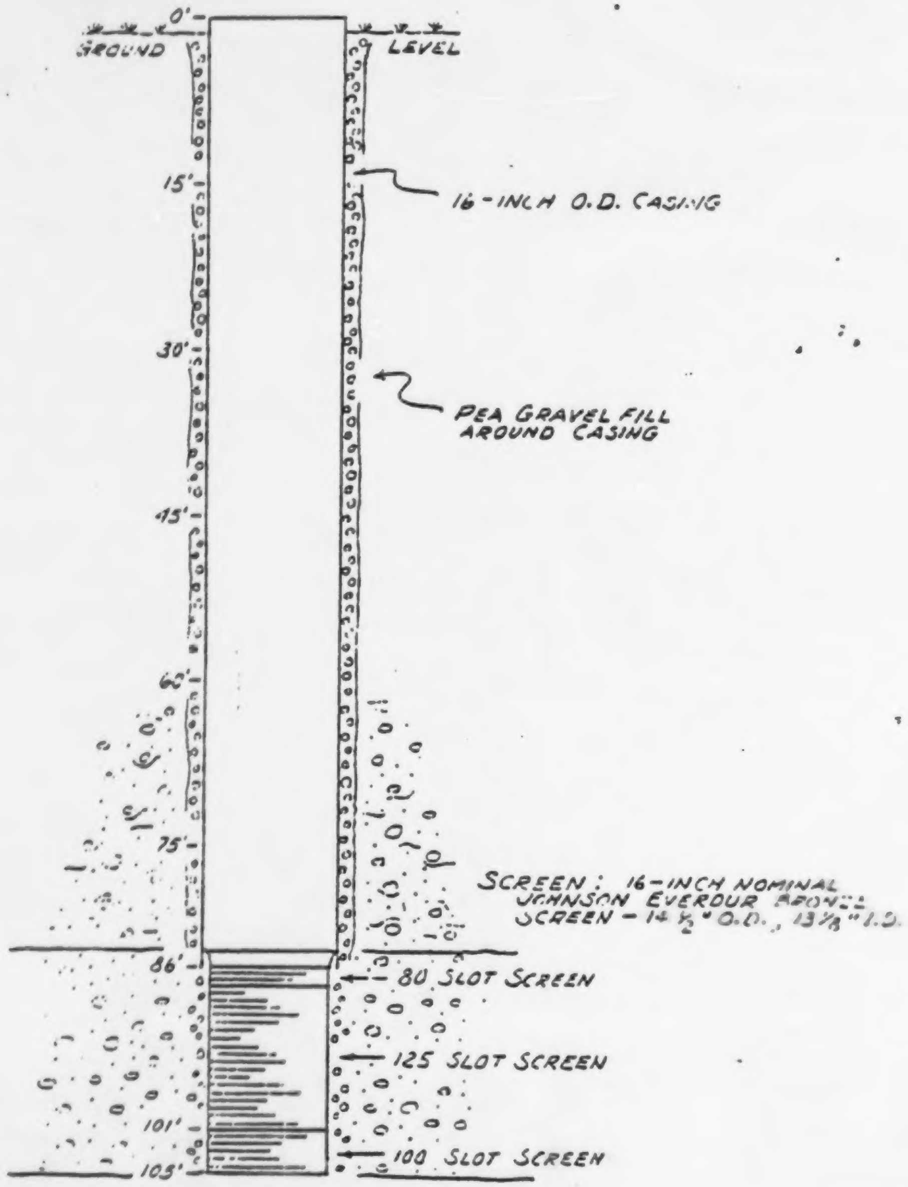
TEST WELL NO. 2 AT PONDERS CORNER


GROUND LEVEL
11' — 11'- GRAVEL & SAND, LOOSE
25' — 14'- HARDPAN
83' — 58'- TIGHT GRAVEL & SAND, SOME WATER BELOW 50'
105' — 22'- GRAVEL & SAND, WATER BEARING
123' — 18'- SAND AND SOME GRAVEL
128' — 5'- CLAY, BLUE, SANDY
180' — 52'- SAND, BLUE, FINE
187' — 7'- HARDPAN
205' — 18'- GRAVEL, CEMENTED
213' — 8'- SAND & COARSE GRAVEL, TIGHT AT BASE
PUMP TESTED - 213' TO 242'
242' — 29'- SAND & COARSE GRAVEL
260' — 18'- CLAY, BLUE
265' — 5'- HARDPAN
287' — 22'- GRAVEL, CEMENTED
304' — 17'- SAND, FINE, MUDDY
313' — 9'- SAND, COARSE AND SOME GRAVEL
340' — 27'- CLAY, SANDY
370' — 30'- SAND, FINE, HARD PACKED
373' — 3'- SANDY CLAY
386' — 13'- SAND & GRAVEL
394' — 8'- CLAY, BLUE, SANDY
408' — 14'- CLAY, GRAY
460' — 52'- HARDPAN, YELLOW
465' — 5'- GRAVEL, CEMENTED
469' — 4'- SAND & GRAVEL
510' — 41'- CEMENTED GRAVEL & HARDPAN

HOLE BOTTOMED AT 510'

LAKEWOOD WATER DISTRICT PIERCE COUNTY, WASHINGTON	ROBINSON AND ROBERTS GROUND WATER GEOLOGISTS TACOMA, WASHINGTON John W Robinson	SEPT. 24, 1957
DRILLED BY: L.R. GAUDIO DRILLING CO.		A-433, H.M.

CONSTRUCTION DETAILS
OF WELL H-2 AT PONDERS CORNER


0'
GROUND
LEVEL
15'
16-INCH O.D. CASING
30'
PEA GRAVEL FILL AROUND CASING
45'
60'
75'
SCREEN: 16-INCH NOMINAL JOHNSON EVERDUR BRONZE SCREEN - 14 ½" O.D., 13⅞" I.D.
86'
80 SLOT SCREEN
125 SLOT SCREEN
101'
100 SLOT SCREEN
105'

LAKEWOOD WATER DISTRICT PIERCE COUNTY, WASHINGTON	ROBINSON AND ROBERTS GROUND WATER GEOLOGISTS TACOMA, WASHINGTON John W. Robinson	SEPT 24, 1959
DRILLED BY L.R. GAUDIO DRILLING CO.		A-434, H.N.

APPENDIX B - SITE SAFETY PLAN

ecology and environment, inc.
108 SOUTH WASHINGTON, SUITE 302, SEATTLE, WASHINGTON 98104, TEL. 206-624-9537
International Specialists in the Environmental Sciences

DATE: January 28, 1983

TO: Dave Dahlstrom, CSD

FROM: Thomas Tobin, RSC
Region X FIT

Thomas A. Tobin
1-26-83

SUBJ: Site Safety Plan for Sampling
Groundwater Monitoring Wells
Lakewood Site, Pierce County
Washington

REF: TDD R10-8301-08

CC: Donald Zelazny, ZPMO

Enclosed is the site safety plan for sampling groundwater monitoring wells at Lakewood, Washington (see attached figures).

Sampling personnel will not wear respiratory protection equipment because the respirable zone above the wells has not been found to contain volatile organics. Contaminated clothing (butyl gloves, apron, helmet) will be removed and either will be cleaned with soap and water at the site or will be bagged for later off-site cleaning. Paper towels and latex gloves that are used for cleaning the bailer and for collecting the samples will be bagged for later off-site disposal. The field team will bring its own water for cleaning and for drinking.

Water generated from the purging of the groundwater monitoring wells will be disposed of on the ground by the well.

TT:jg
enclosure
attachments

recycled paper

ECOLOGY AND ENVIRONMENT, INC.
FIELD INVESTIGATION TEAM
SITE SAFETY PLAN

A. GENERAL INFORMATION

SITE: Lakewood TDD NO: R10-8301-08

WSTS NO:

LOCATION: Pierce County, Washington

PLAN PREPARED BY: Thomas Tobin DATE: January 28, 1983

APPROVED BY: Thomas Tobin, RSO DATE: January 28, 1983

OBJECTIVE(S): Sample FIT-installed groundwater monitoring wells at Lakewood, Pierce County, Washington.

PROPOSED DATE OF INVESTIGATION: January 31 - Febuary 4, 1983

BACKGROUND REVIEW: Complete: X Preliminary:

DOCUMENTATION/SUMMARY: OVERALL HAZARD: Serious: Moderate: Low: X Unknown:

B. SITE/WASTE CHARACTERISTICS

WASTE TYPES(S): Liquid X Solid Sludge Gas

CHARACTERISTIC(S): Corrosive Ignitable Radioactive Volatile X Toxic Reactive Unknown Other

FACILITY DESCRIPTION: Not applicable (N/A)

Principal Disposal Method (type and location): N/A

Unusual Features (dike integrity, power lines, terrain, etc.)

Status: (active, inactive, unknown) N/A

History: (Worker or non-worker injury; complaints from public; previous agency action):

C. HAZARD EVALUATION

In June, 1981, the Lakewood Water District and the EPA detected low levels of organics in Lakewood Production Well H-2 (see EPA memo, 7-19-81); this well has been taken out of service. FIT, along with the Region X EPA, supervised the drilling of 25 groundwater monitoring wells around H-1 and H-2; FIT also provided OVA and HNU capability. The levels of organics in the FIT-installed wells is very low (ppb range) as determined by the use of the OVA and EPA Region X Laboratory. As the levels of organics in the Lakewood wells (FIT wells - 25) is very low and there does not appear to be a problem with inhalation, no respiratory protection is thorugh necessary. If conditions change during the sampling (i.e., the OVA/HNU detects high levels of organic vapors in the respirable zone) while the wells are being purged, the sampling team will put on their Ultra-Twin Respirators with the appropriate cartridge and continue with the sampling of wells. The samplers will be protected against any percutaneous dangers.

D. SITE SAFETY WORK PLAN

PERIMETER ESTABLISHMENT: Map/Sketch Attached X Site Secured? YES

Perimeter Identified? YES Zone(s) of Contamination Identified? NO

PERSONAL PROTECTION

Level of Protection: A ___ B ___ C ___ D X

Modifications: Butyl rubber apron, butyl rubber gloves, surgical gloves, winter coveralls, hard hats with face shield (face shield optional) will be worn.

Surveillance Equipment and Materials: OVA, HNU, stainless-steel bailer, air drive pump, sampling materials, Keck electric pump.

DECONTAMINATION PROCEDURES:

See cover memo.

Special Equipment, Facilities, or Procedures:

None

SITE ENTRY PROCEDURES:

Team will be briefed by the field team leader prior to entering the site.

Team Member	Responsibility
Carol Mitrani	Sampling Team
Peter Evers	Pumper/OVA Operator/Safety Person
Jackie Betz	Field Technician/Documentation
Andy Thomas	Pump Operator/Sampler
Thomas Tobin	Sampler
Kwasi Boateng	Team Leader

WORK LIMITATIONS (Time of day, etc.): None

INVESTIGATION-DERIVED MATERIAL DISPOSAL: Waste water from purged wells will be left on-site (Region X EPA agrees with this policy). Disposables will be removed by the field team.

E. EMERGENCY INFORMATION

LOCAL RESOURCES

Ambulance Pierce County 383-5416

Hospital Emergency Room Lakewood General Hospital, 5702 100th St., Lakewood 474-0561

Poison Control Center Mary Bridge Children's Hospital 272-1281

Police Pierce County 593-4911

Fire Department Lakewood Fire Department #2 588-5217

Airport Sea-Tac, Pacific Highway (south)

Explosives Unit Pierce County Police Dept. 593-4911

EPA Contact Fred Wolf, ESD 442-0887

SITE RESOURCES

Water Supply The sampling team will bring their own water supply

Telephone Lakewood Water District office or local pay phone

Radio None

Other

EMERGENCY CONTACTS

1.	Dr. Raymond Harbison (University of Arkansas) . . . (MEDTOX)	(501) 661-5766 or 661-5767 (501) 370-8263 (24 hour)
2.	Regional Safety Officer	Thomas Tobin 624-9537/524-2850
3.	FIT Leader	Hussein Aldis 624-9537/881-6636
4.	FIT office	Region X; 206-624-9537
5.	Ecology and Environment, Inc. NPMO	(703) 522-6065 (24 hour; call forwarding)
6.	Regional Health Maintenance Program Contact	
7.	TAT Emergency Paging System	(716) 882-2804
8.	CHEMTREX	1-800-424-9300
9.	ZPMO	(703) 522-6065
10.	Dave Dahlstrom	(716) 632-4491/741-2884

F. EMERGENCY ROUTES

(Give road or other directions; Attach Map)

HOSPITAL: Pacific Highway and New York Avenue then N.E. on Pacific Highway to Bridgeport Way (N) on to Bridgeport Way to 100th St. Left on 100th St. to Lakewood General Hospital.

OTHER:

EQUIPMENT CHECKOUT

SCBA ☐ CYLINDERS ☐
APR ☒ CARTRIDGES ☒
EXPLOSIMETER ☐
O_2 INDICATOR ☐
DRAEGER PUMP ☐ TUBES ☐
RADIATION SURVEY METER ☐
RADIATION CONTAMINATION METER ☐

EYE WASH UNIT ☒
FIRST AID KIT ☒
DRINKING WATER SUPPLY ☒
PERSONAL CLOTHING ☒
DECONTAMINATION MATERIALS ☒
Dosimeter badges ☒
OVA ☒
HNU ☒

M E M O

TO: All TAT/FIT Team Members

THRU: Regional Safety Officers

FROM: David L. Dahlstrom, Corporate Safety Director

SUBJECT: Emergency Incident Response Procedures

DATE: July 31, 1981

cc: Dr. R. Harbison, Dr. R. James, Dr. J. Nolan, Dr. E. Carr,
Dr. C. Zenz R. Gray, ~~L. Adams~~, G. Gallagher

So as to provide better and more comprehensive response service in the event of an emergency exposure in the field requiring immediate medical treatment, the procedure will be to initially contact Dr. Raymond Harbison via the emergency toxicological phone system. If for any reason Dr. Harbison does not respond within 15 minutes of activation, you are to contact your respective national program offices.

Since the TAT NPMO operates on a beeper system that is manned 24 hours a day, contact with a responsive individual will occur within minutes of activation. The FIT NPMO operates after hours on a call forwarding basis. Therefore, in the rare possibility that someone from this office cannot be reached, all FIT are to contact the TAT NPMO paging system. The respective numbers are:

Emergency Toxicological Phone System	501/370-8263
FIT Emergency Call-Forwarding System	703/522-6065

Please remember three things if an emergency incident occurs:

1. without hesitation get the injured person to the nearest treatment facility immediately;
2. contact Dr. Harbison or responsible emergency system, and,
3. contact your respective NPMO to notify them of the emergency.

Under no circumstances should activation of emergency notification systems preclude the immediate care of the injured individual.

Concurrence:

G. A. Gallagher

R. G. Gray

R. Gray

L. Adams

DATE Aug. 19, 1981 (updated August 25, 1981)

JECT: Analysis of Water Samples for Purgeable Halocarbons
from the Lakewood-McChord Field Area.

FROM: Arnold R. Gahler, Chief
Region 10 Laboratory

TO: G. O'Neal, Director
S & A Division

W. Mullen, Chief
Water Supply Branch

The attached table describes purgeable halocarbon concentrations from samples taken from wells in the Lakewood-McChord area as analyzed by R. Rieck.

Samples were analyzed in the priority order suggested by Mr. W. Mullen.

Note: 1,2 (trans)-Dichloroethylene is the same compound as 1,2(trans)-Dichloroethene.

Trichloroethylene is the same compound as Trichloroethene.

Tetrachloroethylene is the same compound as Tetrachloroethene.

RECEIVED
AUG 20 1981
S & A DIVISION

Laboratory Number	Station Name	Concentration Micrograms per/liter
32466	12016 Woodbine Lane	1K*
32428	Shady Lane MHP	1K well
32460	7-11 on 12336 Pacific Highway S.	1K
32492	12812 True Lane S.	1K
32470	12711 Lincoln	1K
32472	5301 Chicago	1K
32474	Lakewood H-2	
	1,2 (trans)-Dichloroethene	63
	Tetrachloroethene	67
	1,1,1-Trichloroethane	1.5
	Trichloroethene	11
32480	12016 Woodbine (Transfer blank)	1K
32481	McChord #832 (Transfer blank)	1K
32482	Lakewood H-2 (Transfer blank)	1K
	Laboratory Blank	1K
32430	McChord #781 Trichloroethene	4.5
32431 (Dupl)	McChord #781 Trichloroethene	5.3
32432	McChord #711 Trichloroethene	1.1
32433 (Dupl)	McChord #711 Trichloroethene	1.3
32440	McChord #832 Chloroform	1.8
32441 (Dupl)	McChord #832 Chloroform	1.8
32450	Lakewood D-3	1K
32452	Lakewood D-2	1K
32454	Lakewood K-2	1K
32456	Lakewood F-2	1K
32458	Lakewood G-1	1K
32434	McChord 190	1K
32436	McChord 3410	1K
32438	McChord 5001	1K
32442	McChord 846	1K

* Compounds not identified within detection limits noted.

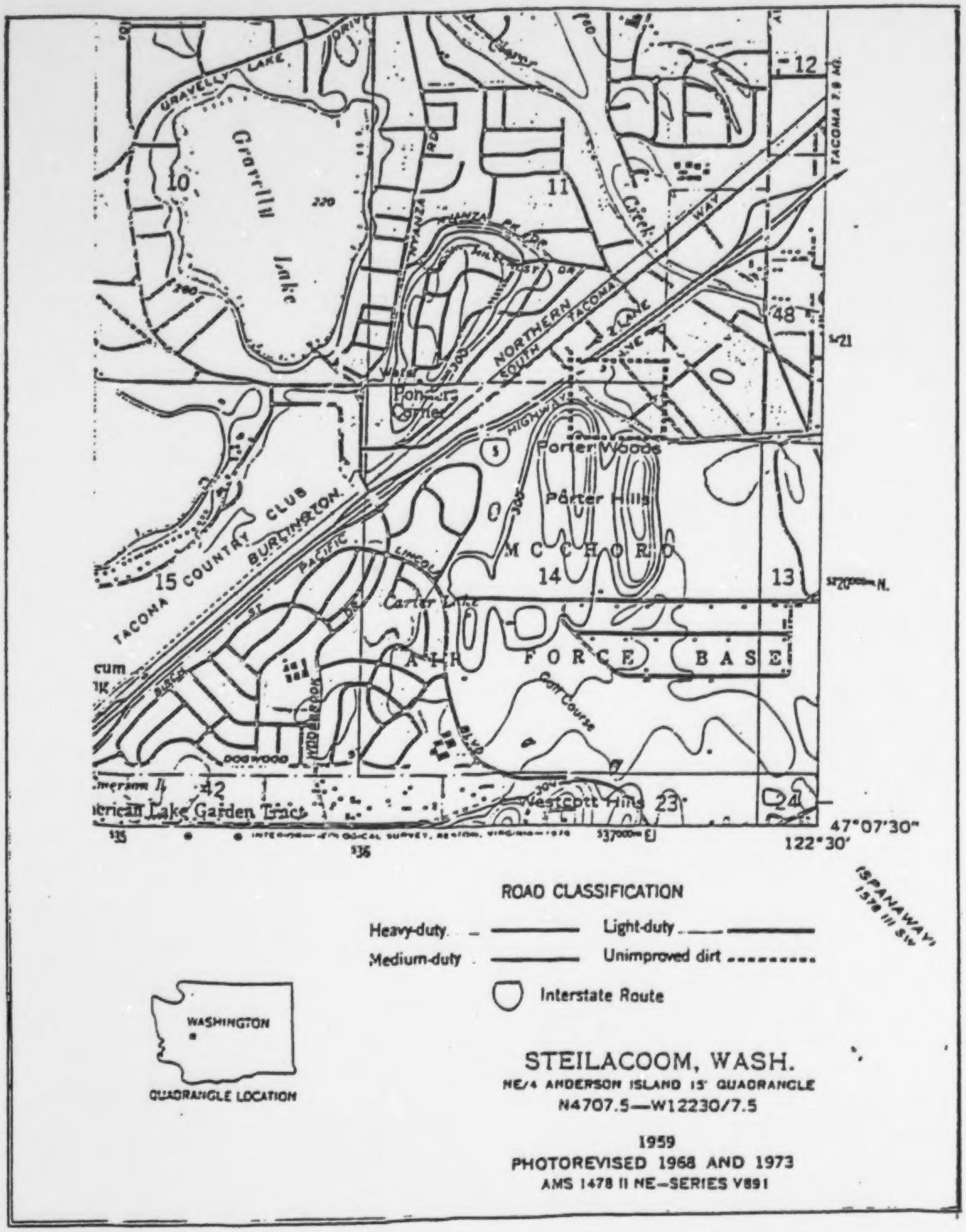

Gravelly Lake
Gravelly Lake Drive
Nyanza Rd
Nyanza Park Dr
Ponders Corner
Northern
South Tacoma Way
Highway
Porter Woods
Porter Hills
McChord
Air Force Base
Carter Lake
Golf Course
Tacoma Country Club
Burlington
Pacific
Lincoln
Westcott Hills
American Lake Garden Tract
Dogwood
Holbrook
Blvd
Tacoma 7.8 Mi.
10
11
12
13
14
15
23
24
42
48
5
47°07'30"
122°30'
ROAD CLASSIFICATION
Heavy-duty
Light-duty
Medium-duty
Unimproved dirt
Interstate Route
WASHINGTON
QUADRANGLE LOCATION
(SPANAWAY)
1578 III SW
STEILACOOM, WASH.
NE/4 ANDERSON ISLAND 15' QUADRANGLE
N4707.5—W12230/7.5
1959
PHOTOREVISED 1968 AND 1973
AMS 1478 II NE—SERIES V891

FIGURE 1
LOCATION MAP
LAKEWOOD, WASHINGTON

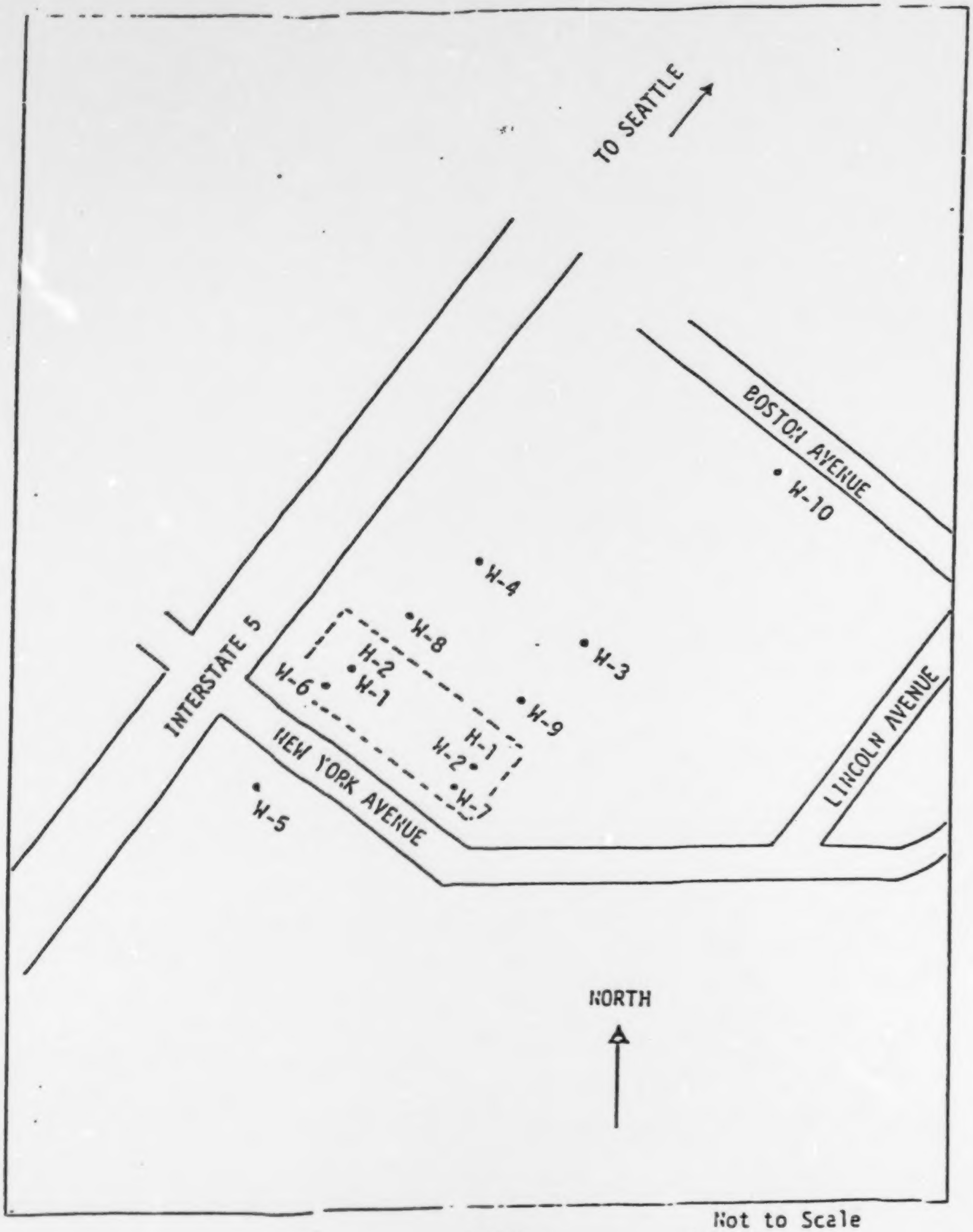

TO SEATTLE
BOSTON AVENUE
W-10
W-4
W-8
W-3
H-2
W-6
W-1
W-9
INTERSTATE 5
H-1
W-2
W-7
NEW YORK AVENUE
LINCOLN AVENUE
W-5
NORTH
Not to Scale

FIGURE 2
LOCATION OF LAKEWOOD
GROUNDWATER MONITORING WELLS 1-10
LAKEWOOD, WASHINGTON

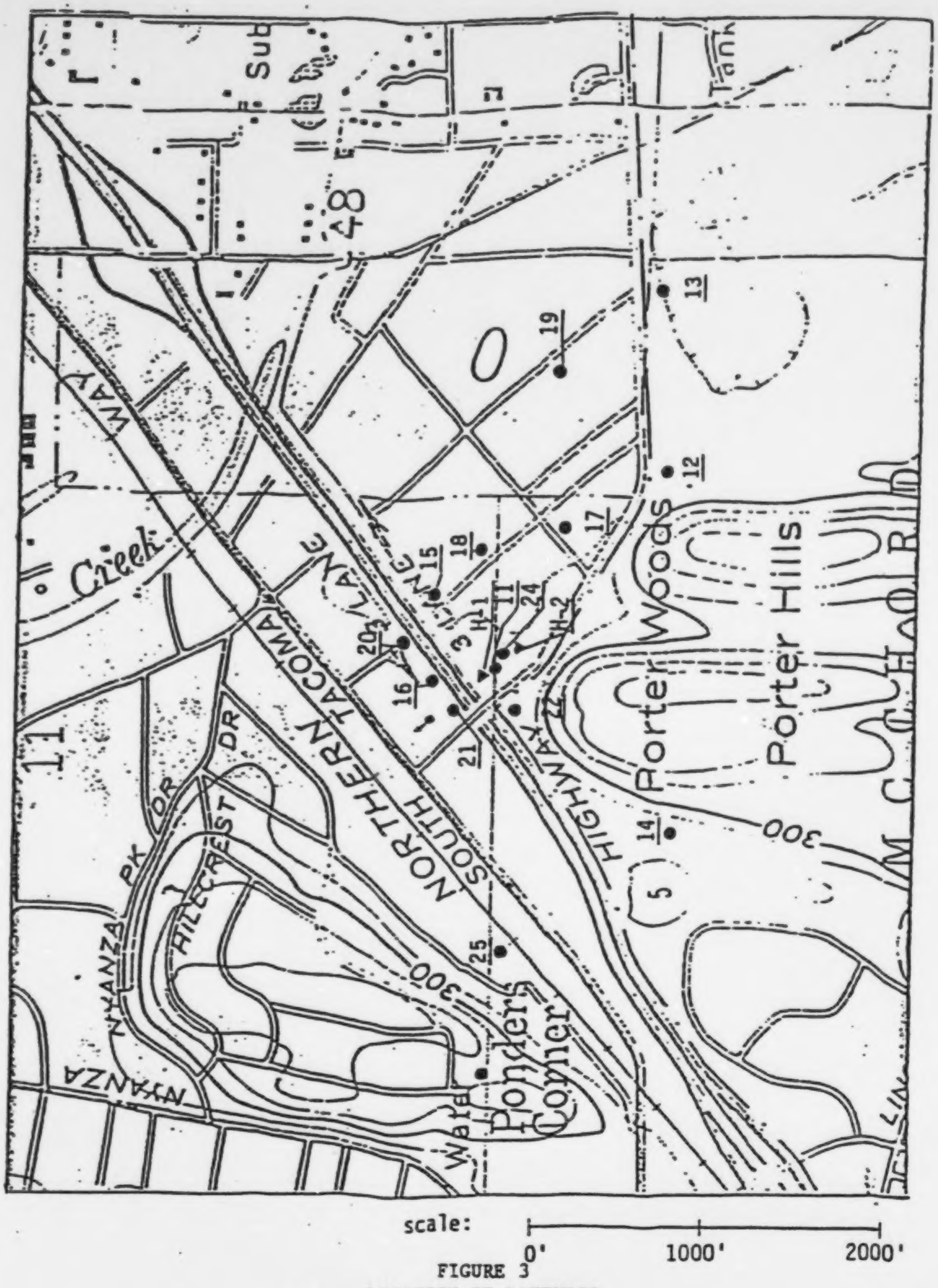

Sub
Tank
48
11
Creek
WAY
NORTHERN
SOUTH TACOMA
LANE
HIGHWAY
Porter Woods
Porter Hills
HILLCREST DR
NYANZA PK DR
NYANZA
Ponders Corner
Water
300
300
5
11
12
13
14
15
16
17
18
19
20
21
22
24
25
3
H-1
H-2
scale:
0'
1000'
2000'

FIGURE 3
LOCATION OF LAKEWOOD
GROUNDWATER MONITORING WELLS 11-25
LAKEWOOD, WASHINGTON

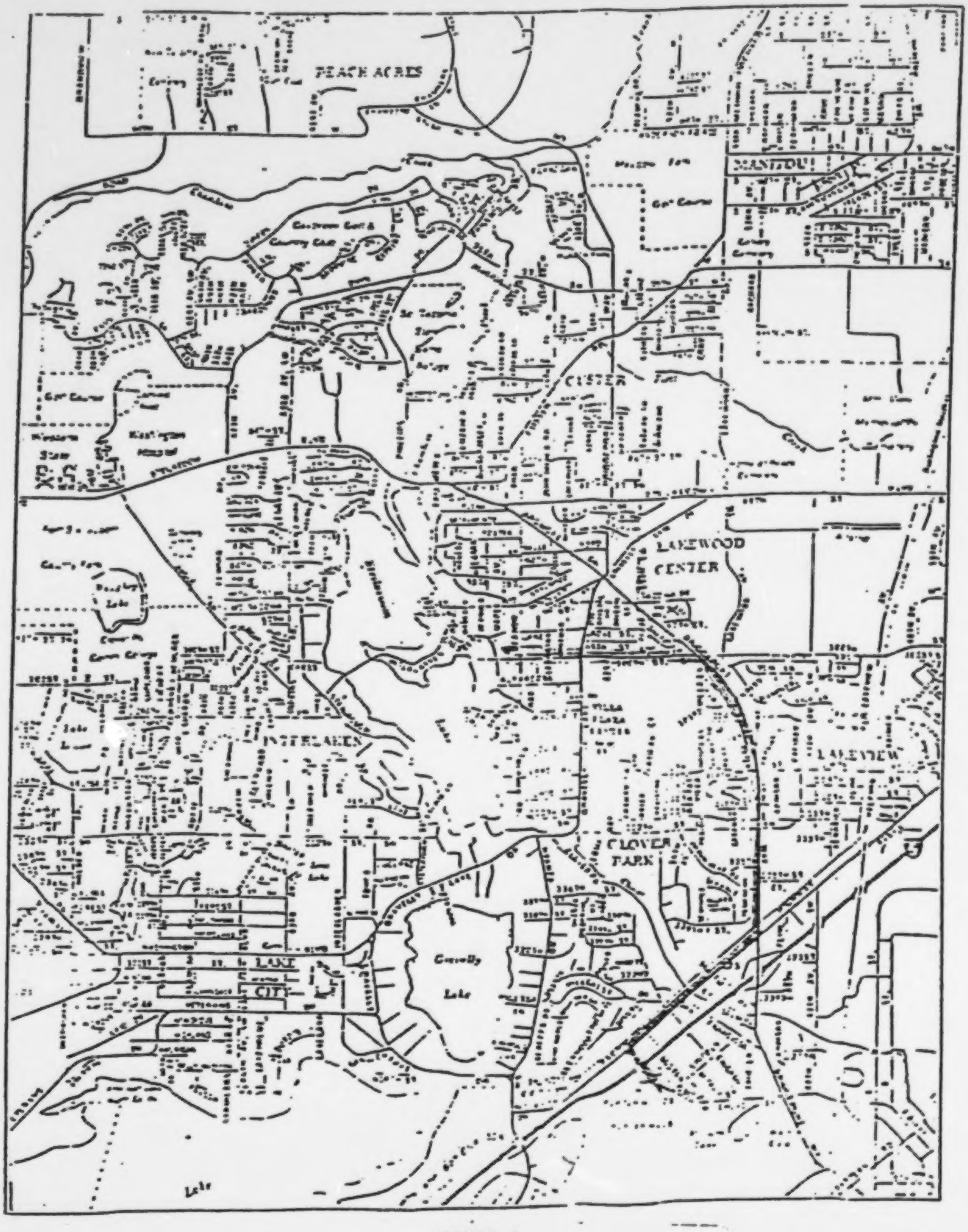

PEACH ACRES
MANITOU
CUSTER
LAKEWOOD
CENTER
INTERLAKEN
LAKEVIEW
CLOVER
PARK
LAKE
CITY
Gravelly
Lake
Lake

FIGURE 4
LOCATION MAP
LAKEWOOD GENERAL HOSPITAL

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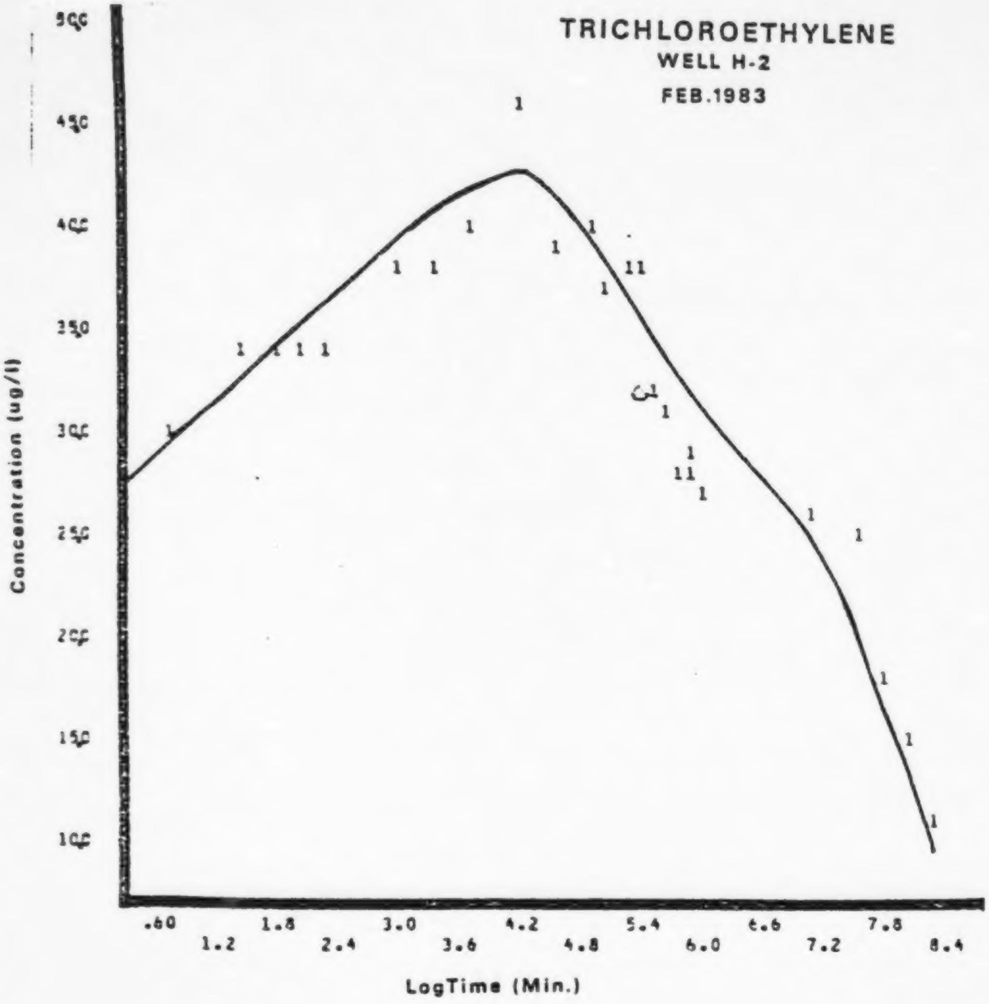
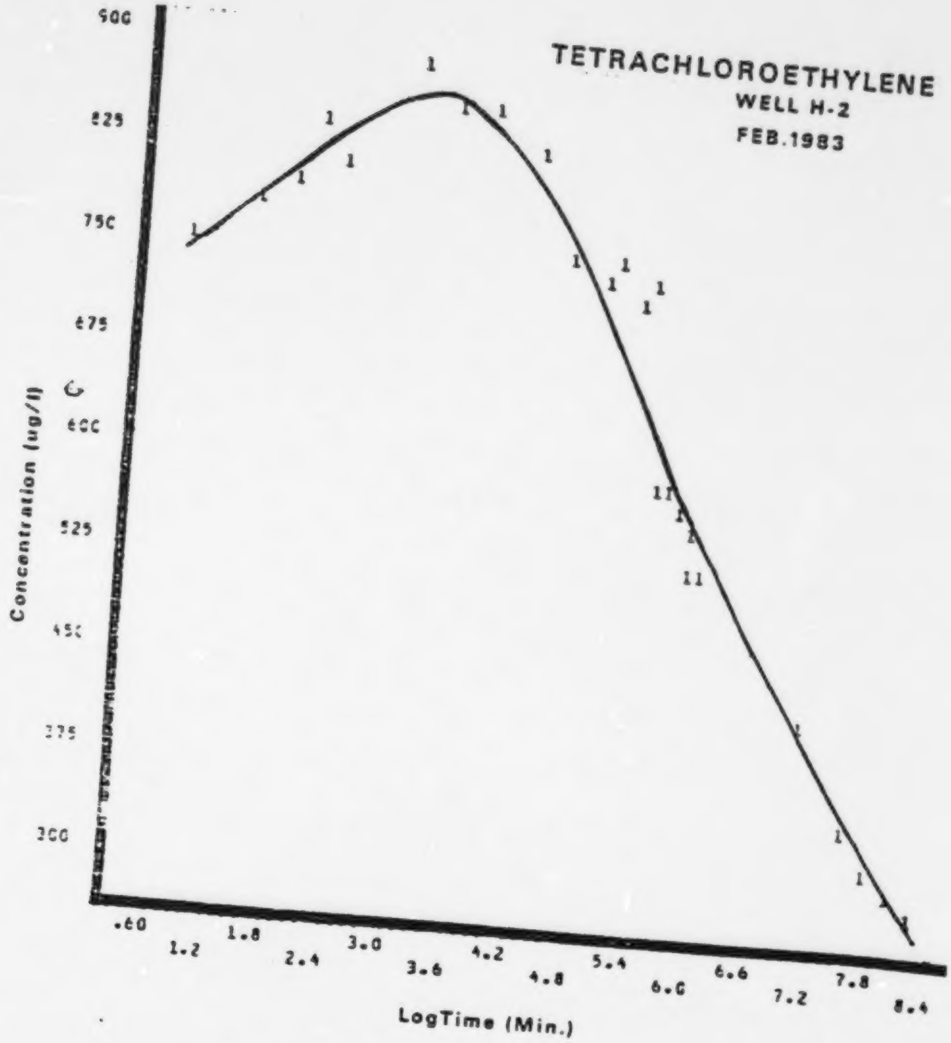
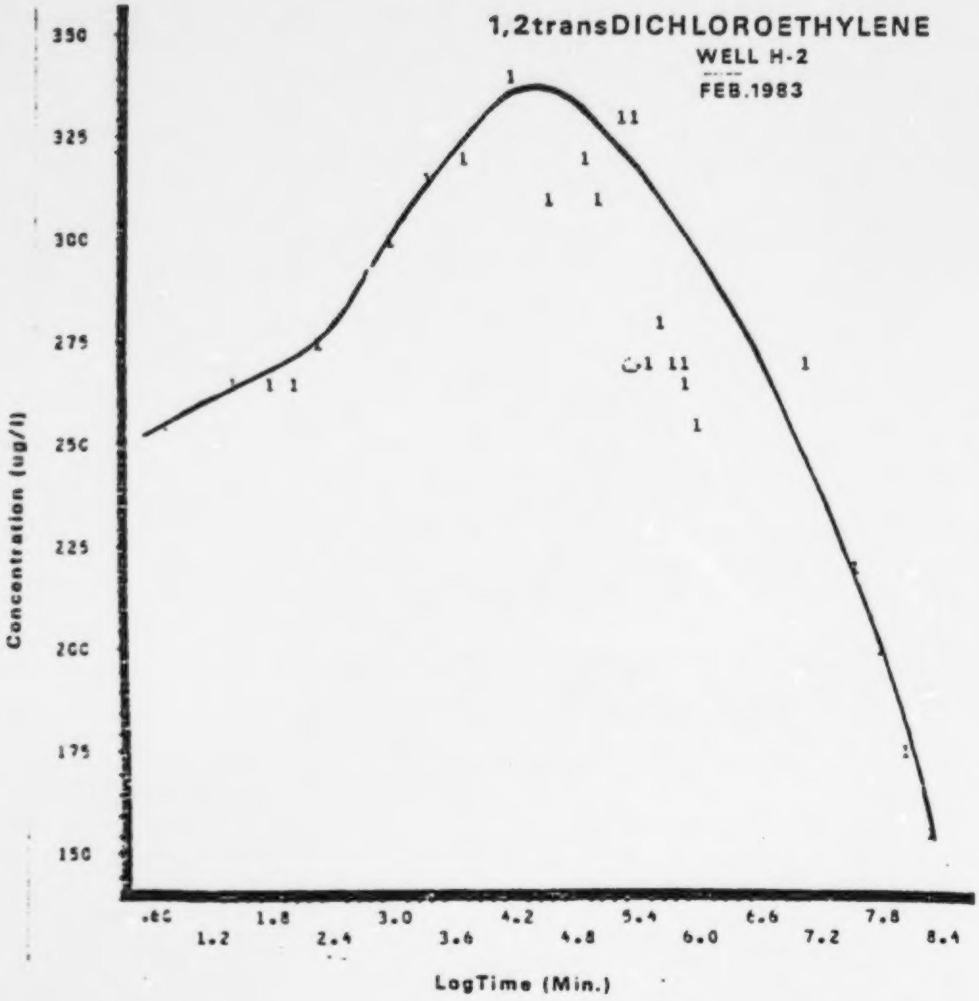
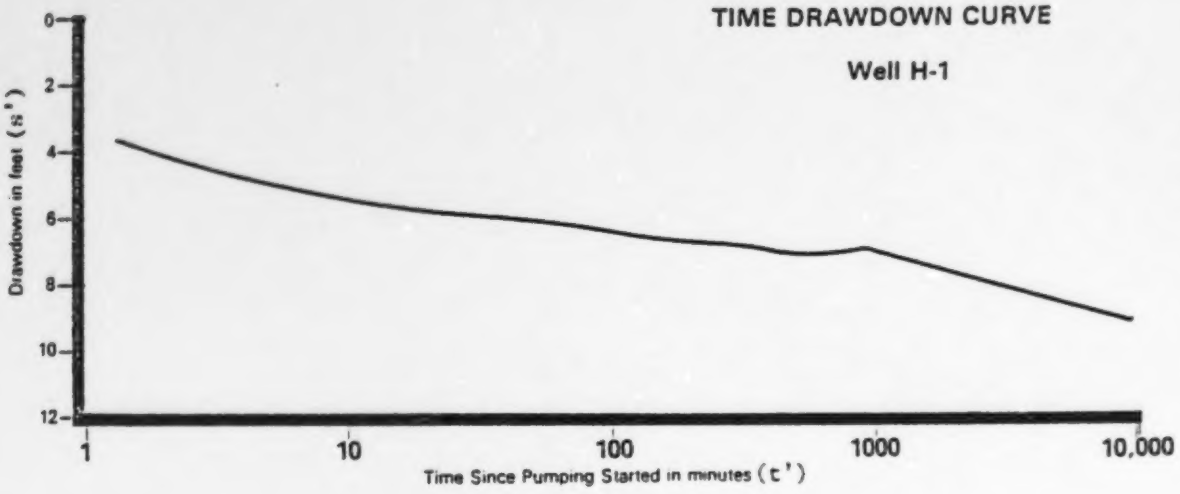
APPENDIX C

CONTAMINANT CONCENTRATIONS AND WELL DRAWDOWN/ RECOVERY CURVES


TRICHLOROETHYLENE
WELL H-2
FEB.1983
Concentration (ug/l)
500
450
400
350
300
250
200
150
100
LogTime (Min.)
.60
1.2
1.8
2.4
3.0
3.6
4.2
4.8
5.4
6.0
6.6
7.2
7.8
8.4

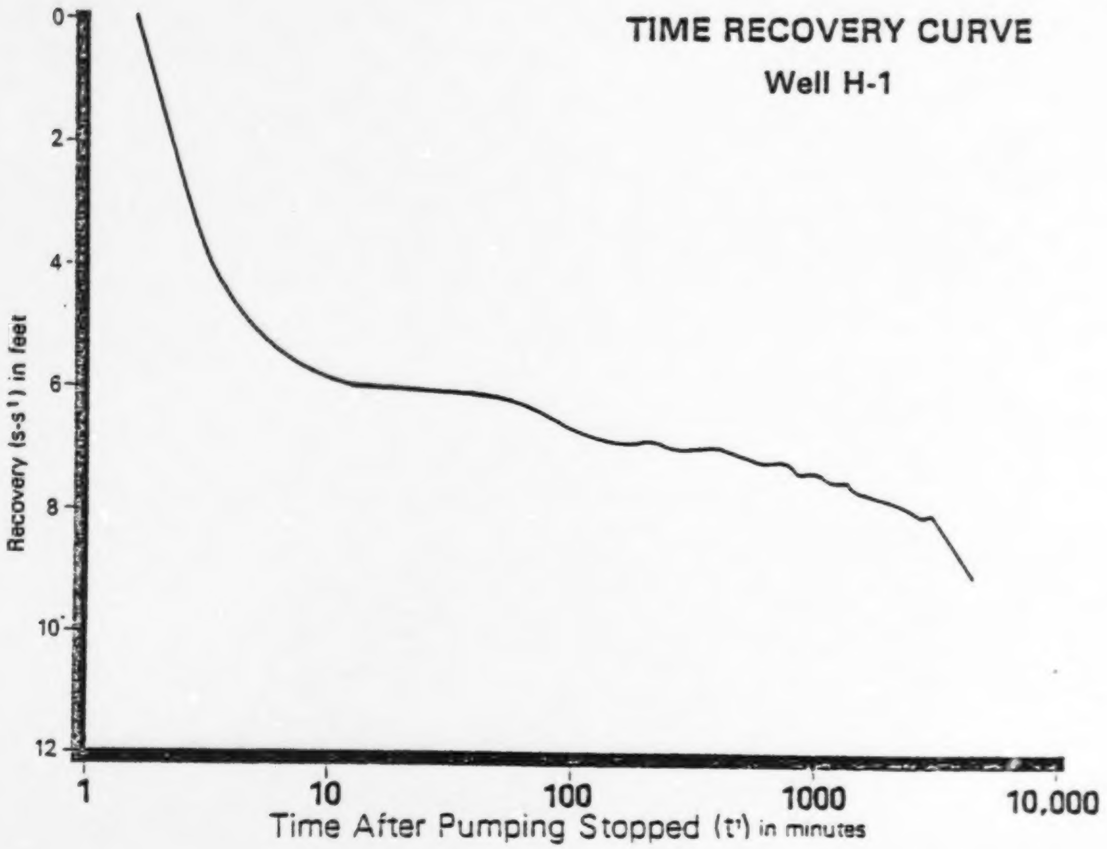

TETRACHLOROETHYLENE
WELL H-2
FEB.1983
Concentration (ug/l)
C
900
825
750
675
600
525
450
375
300
.60
1.2
1.8
2.4
3.0
3.6
4.2
4.8
5.4
6.0
6.6
7.2
7.8
8.4
LogTime (Min.)


1,2transDICHLOROETHYLENE
WELL H-2
FEB.1983
Concentration (ug/l)
350
325
300
275
250
225
200
175
150
LogTime (Min.)
.60
1.2
1.8
2.4
3.0
3.6
4.2
4.8
5.4
6.0
6.6
7.2
7.8
8.4



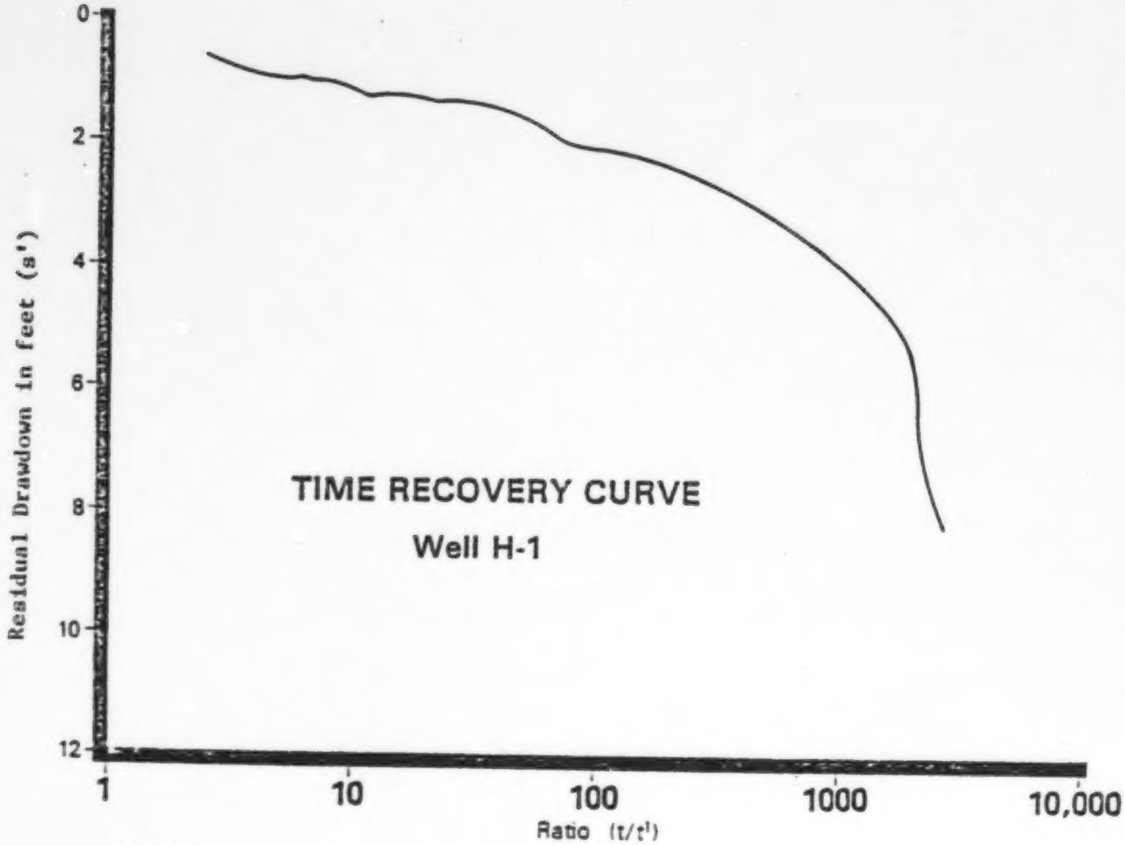
TIME DRAWDOWN CURVE

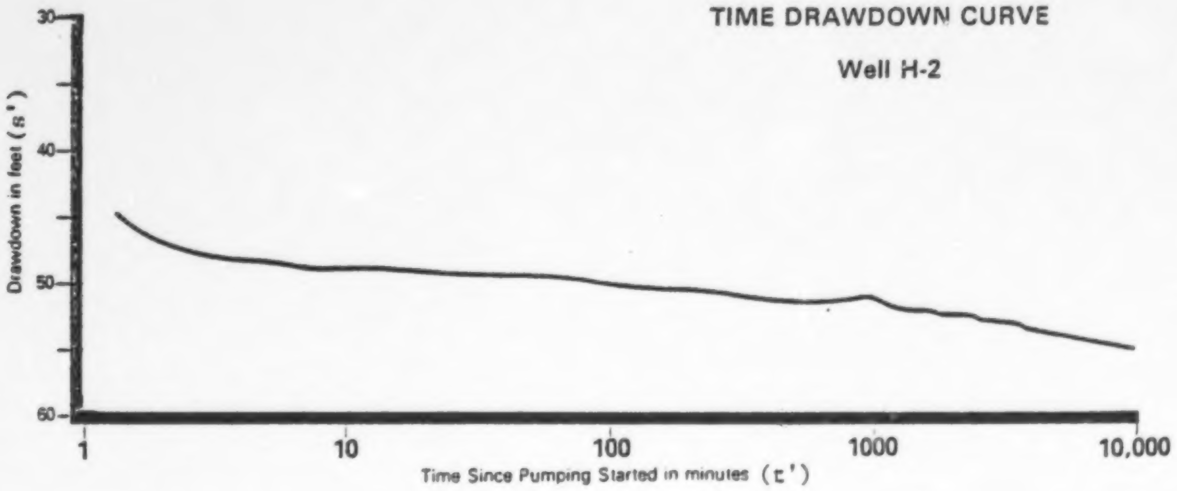
Well H-1

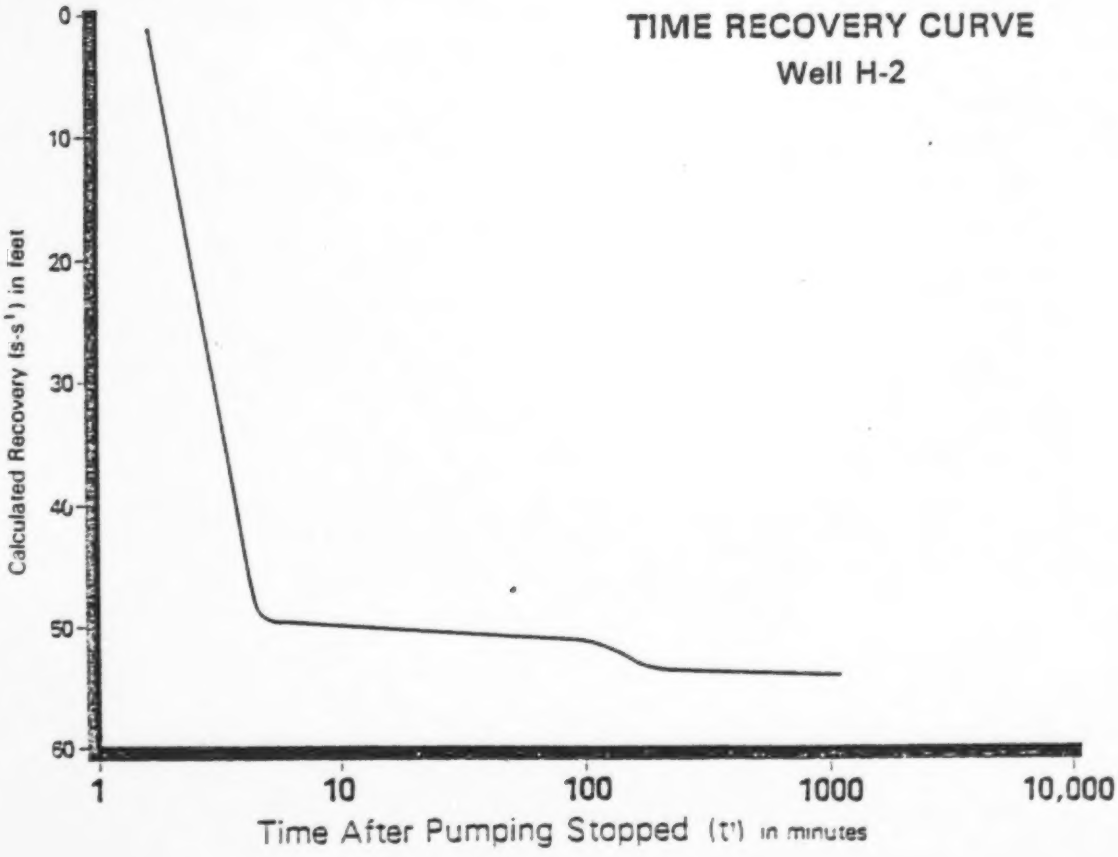


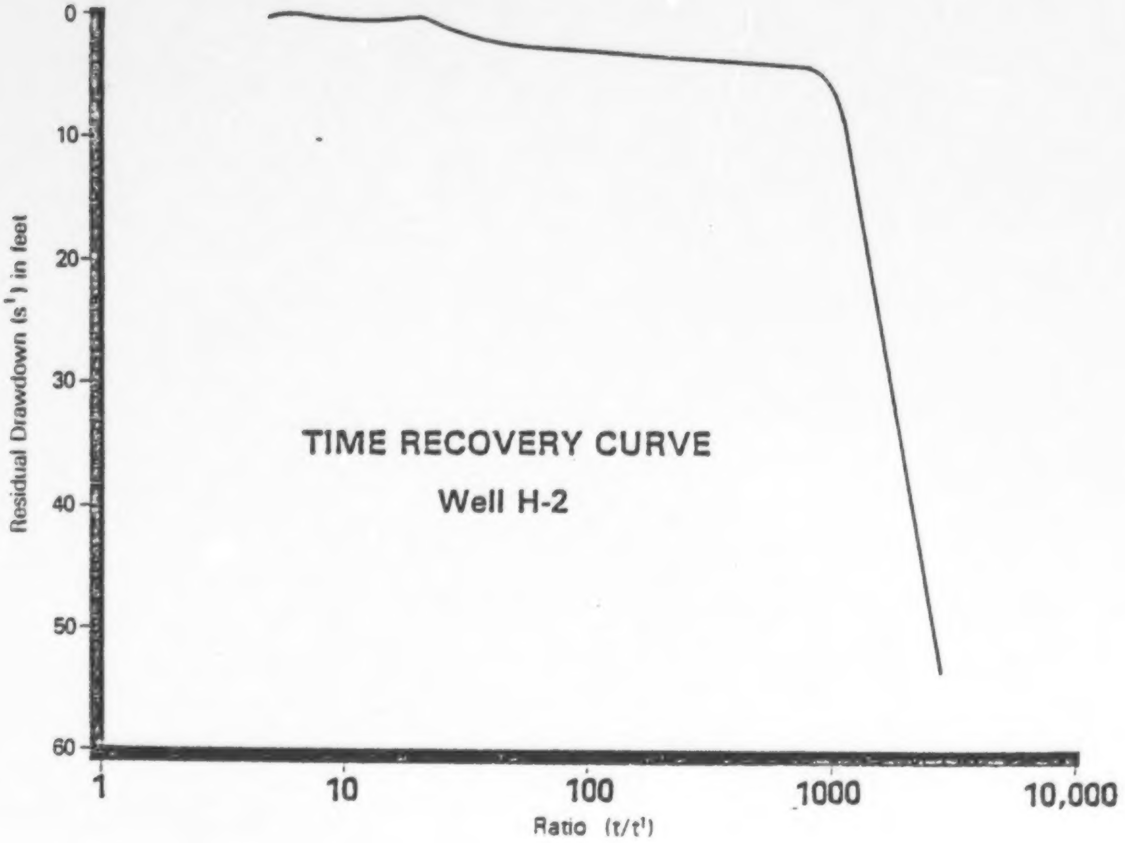
TIME RECOVERY CURVE

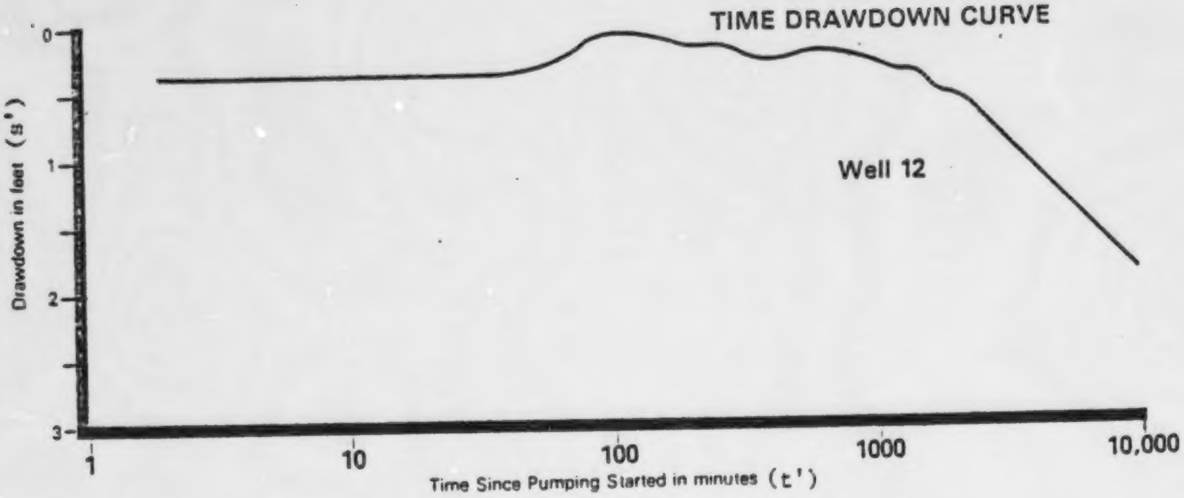
Well H-1

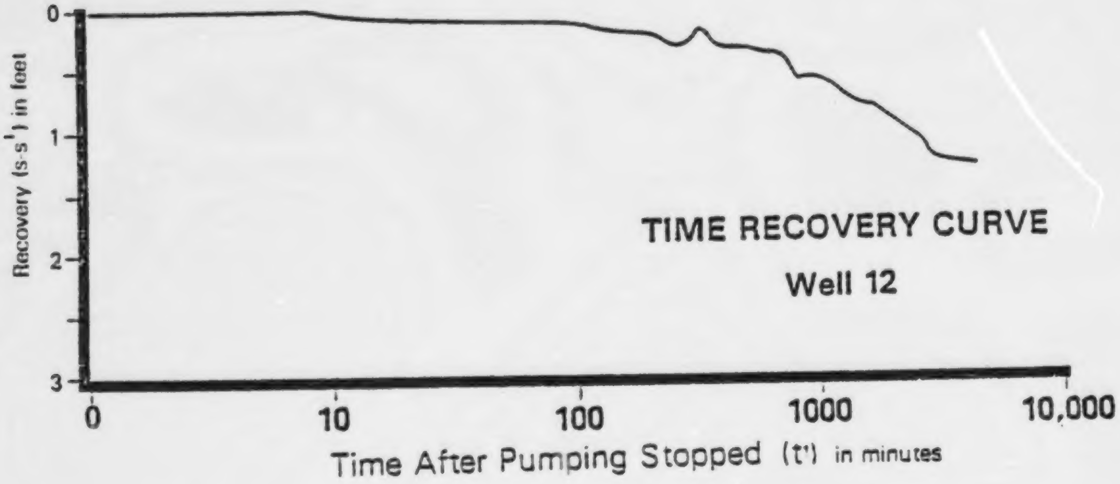

TIME RECOVERY CURVE
Well H-1
Residual Drawdown in feet (s')
0
2
4
6
8
10
12
1
10
100
1000
10,000
Ratio (t/t')

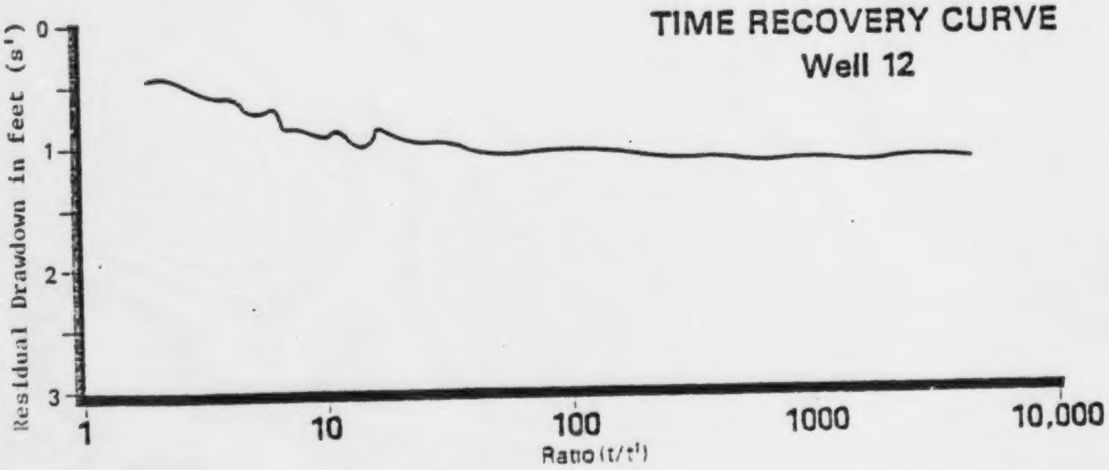

TIME DRAWDOWN CURVE
Well H-2
Drawdown in feet (s')
30
40
50
60
1
10
100
1000
10,000
Time Since Pumping Started in minutes (t')

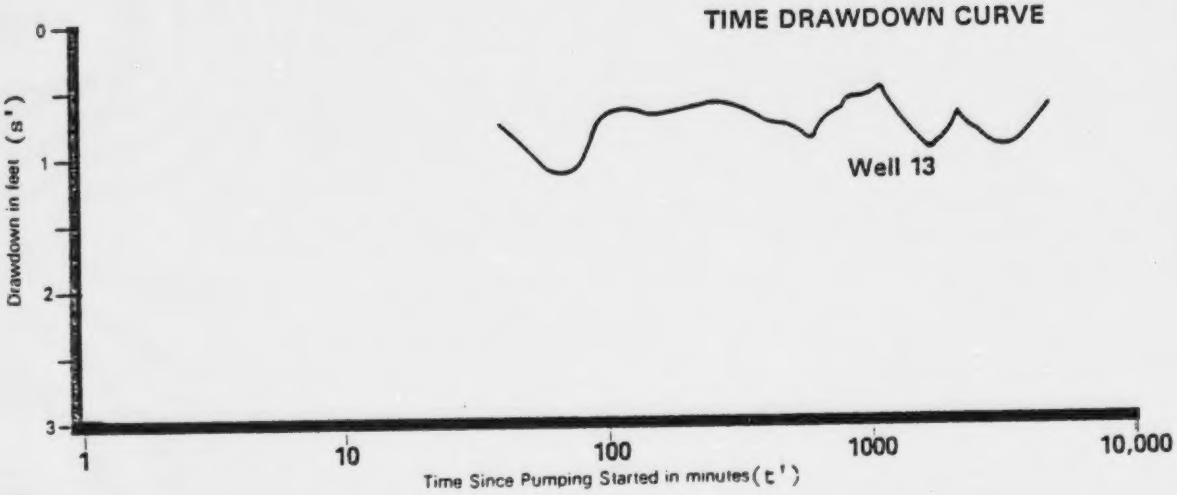

TIME RECOVERY CURVE
Well H-2
Calculated Recovery (s-s') in feet
0
10
20
30
40
50
60
1
10
100
1000
10,000
Time After Pumping Stopped (t') in minutes

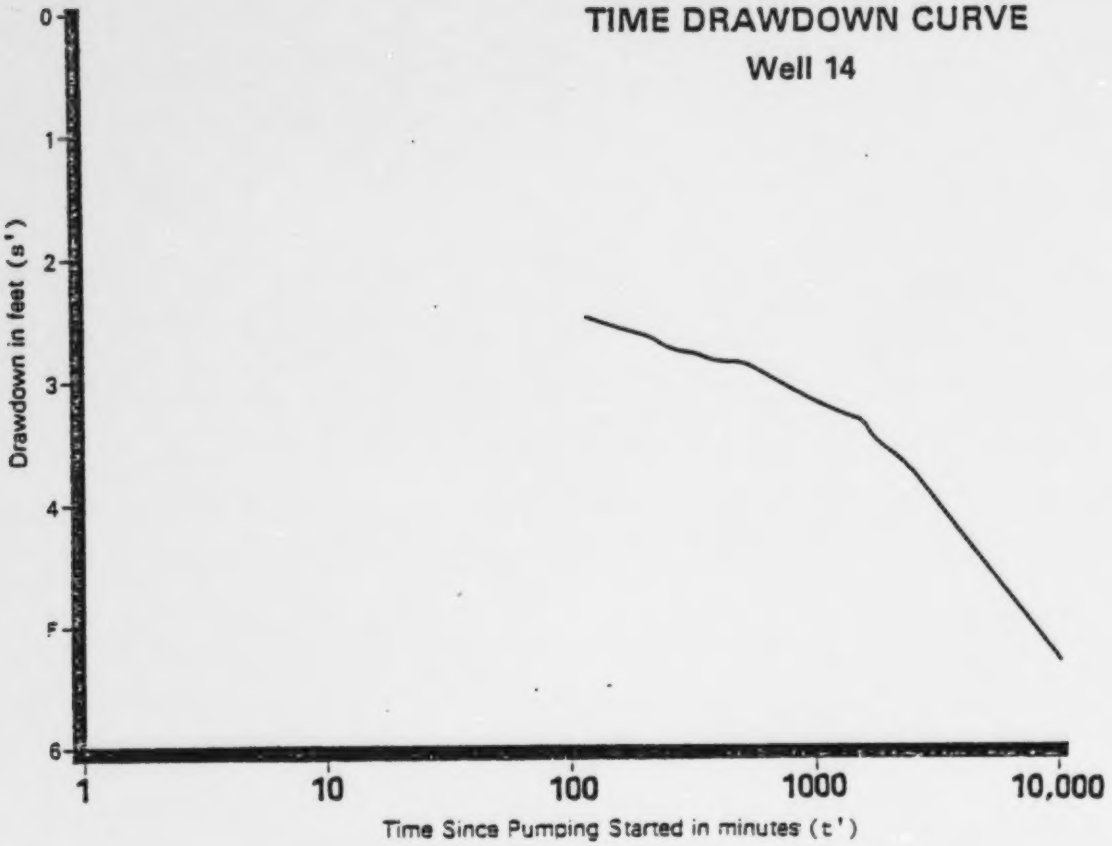

TIME RECOVERY CURVE
Well H-2
Residual Drawdown (s') in feet
0
10
20
30
40
50
60
1
10
100
1000
10,000
Ratio (t/t')

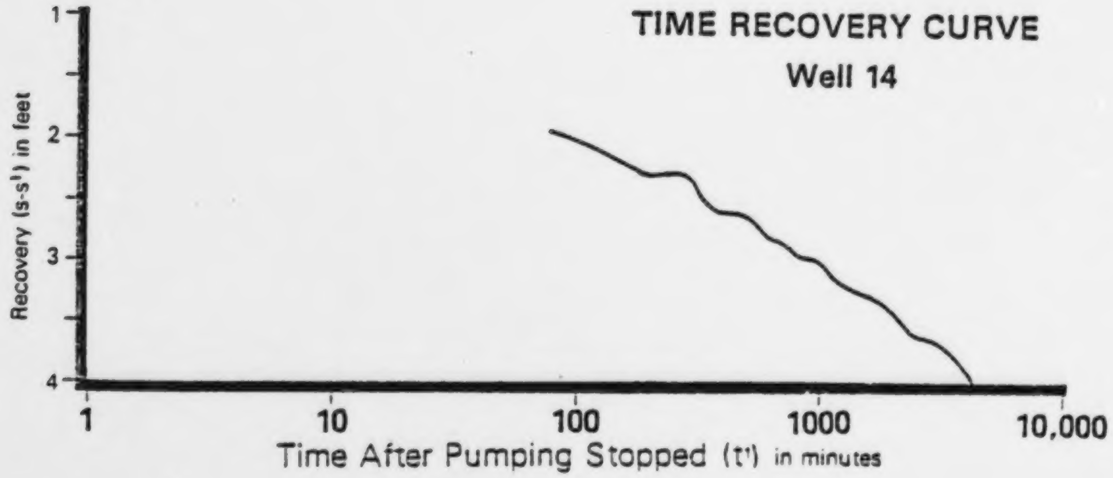

TIME DRAWDOWN CURVE
Well 12
Drawdown in feet (s')
0
1
2
3
1
10
100
1000
10,000
Time Since Pumping Started in minutes (t')

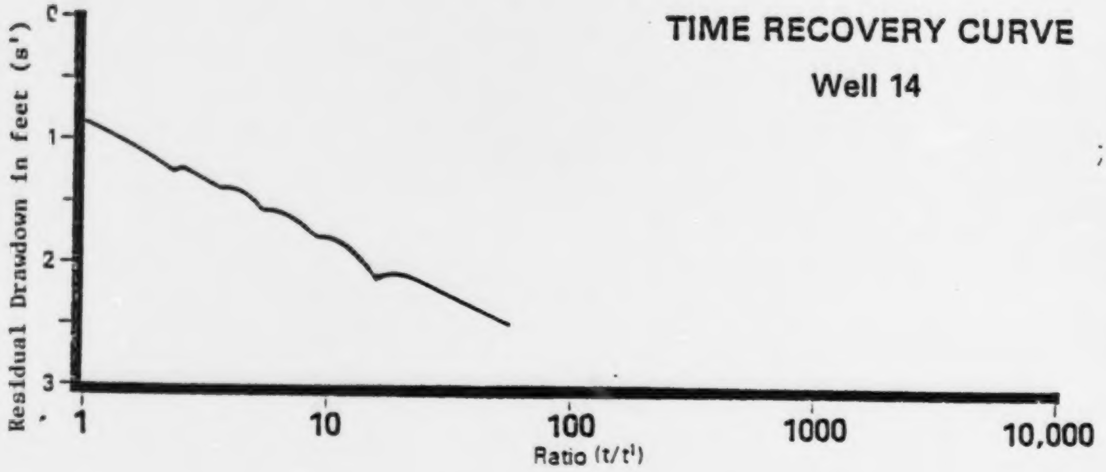

TIME RECOVERY CURVE
Well 12
Recovery (s-s') in feet
0
1
2
3
0
10
100
1000
10,000
Time After Pumping Stopped (t') in minutes


TIME RECOVERY CURVE
Well 12
Residual Drawdown in feet (s')
0
1
2
3
1
10
100
1000
10,000
Ratio (t/t')


TIME DRAWDOWN CURVE
Well 13
Drawdown in feet (s')
0
1
2
3
1
10
100
1000
10,000
Time Since Pumping Started in minutes (t')

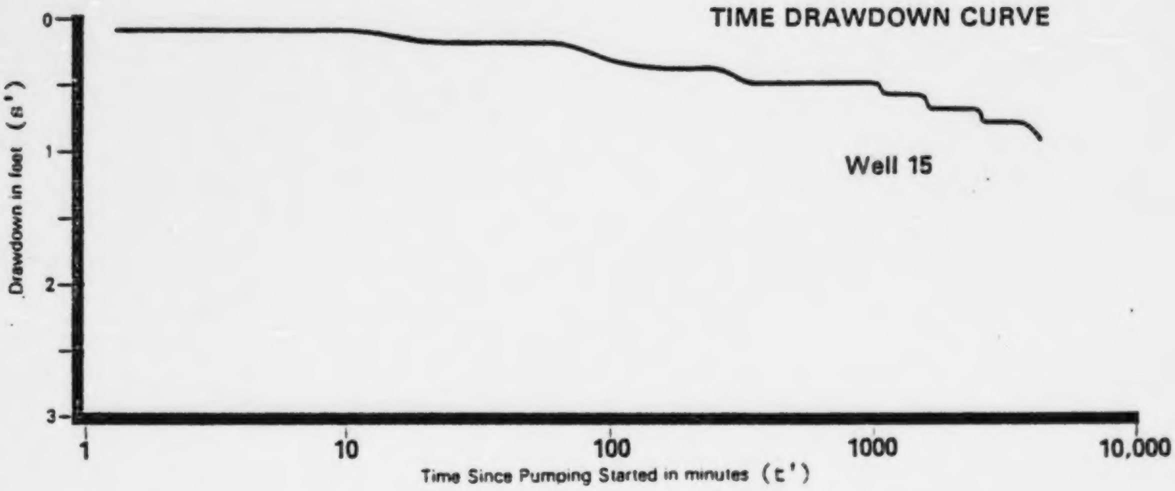

TIME DRAWDOWN CURVE
Well 14
Drawdown in feet (s')
0
1
2
3
4
5
6
1
10
100
1000
10,000
Time Since Pumping Started in minutes (t')

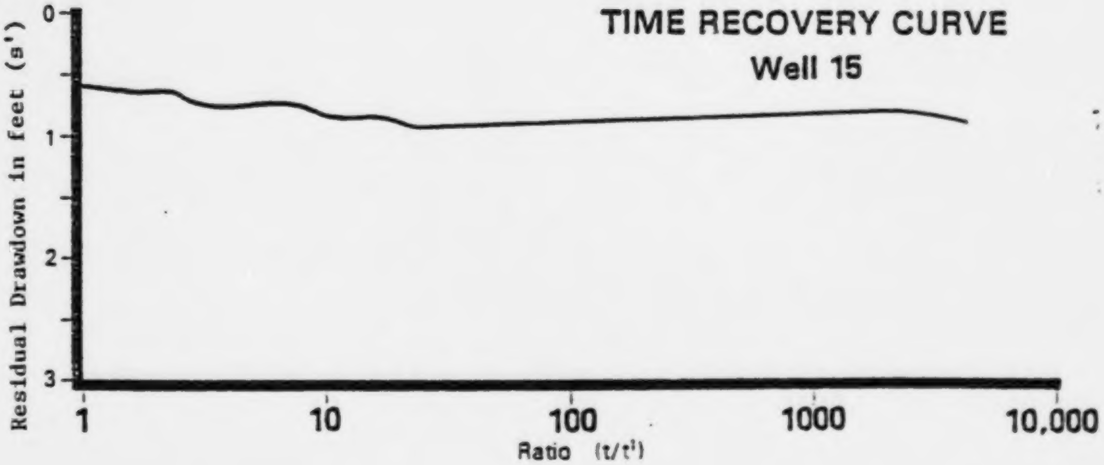

TIME RECOVERY CURVE
Well 14
Recovery (s-s') in feet
1
2
3
4
1
10
100
1000
10,000
Time After Pumping Stopped (t') in minutes

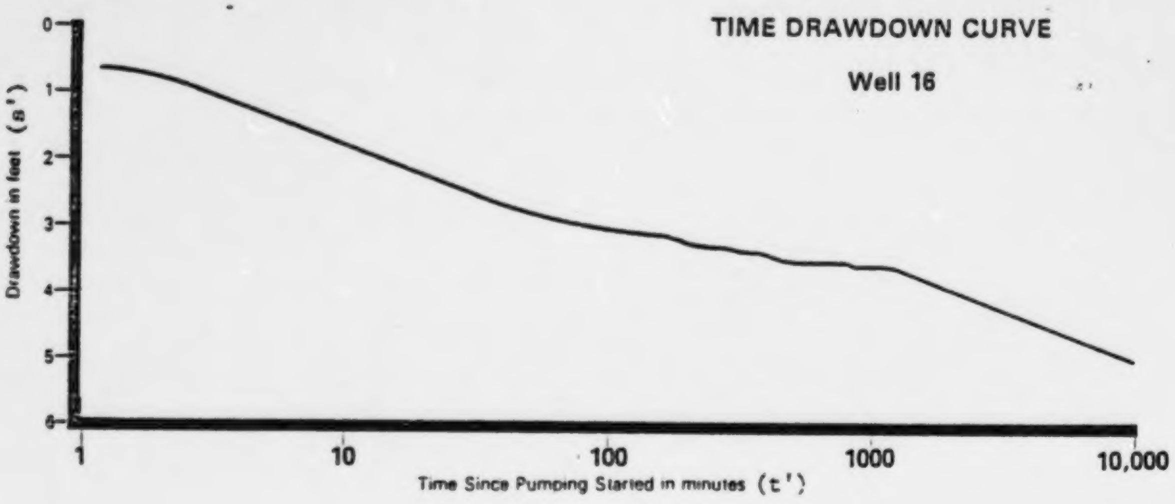


TIME RECOVERY CURVE

Well 14

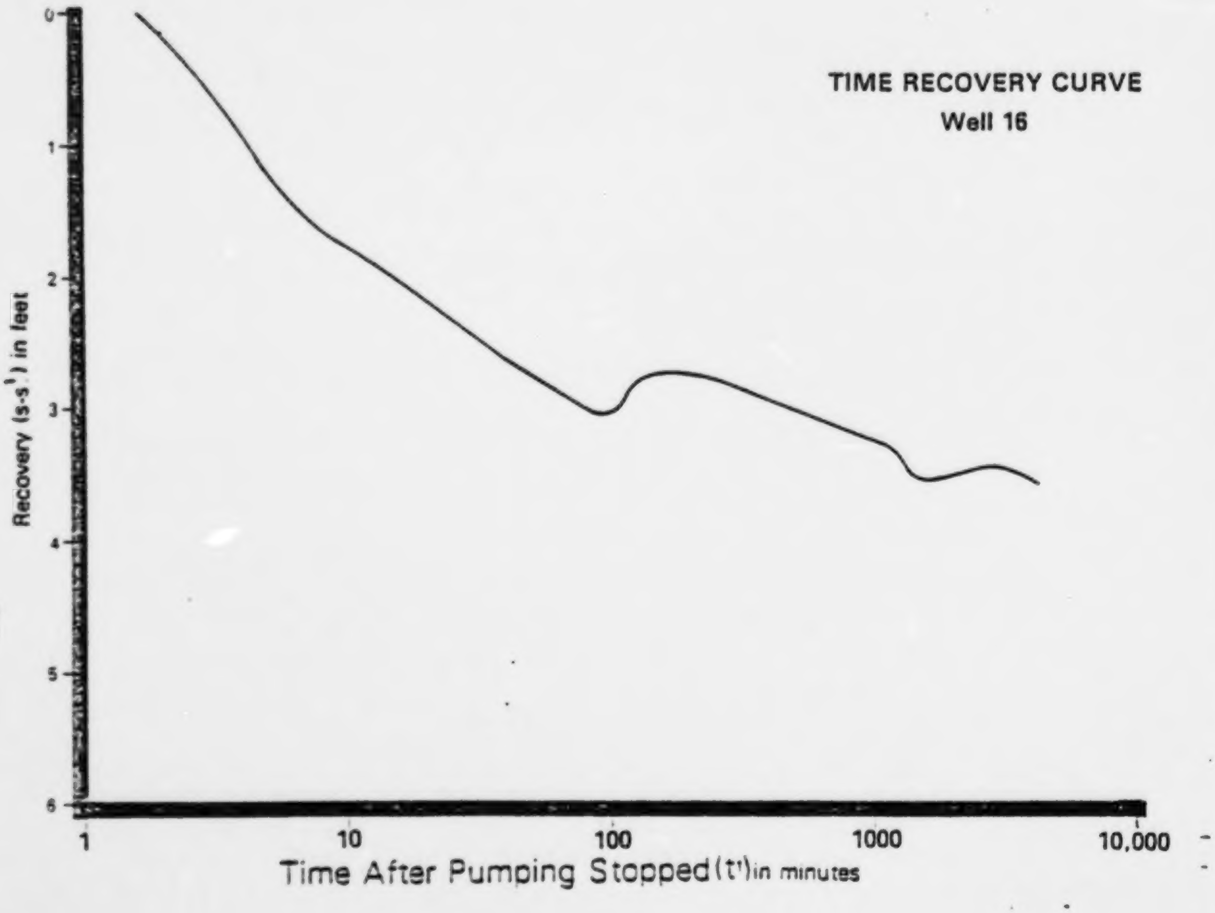

TIME DRAWDOWN CURVE
Well 15
Drawdown in feet (s')
0
1
2
3
1
10
100
1000
10,000
Time Since Pumping Started in minutes (t')


TIME RECOVERY CURVE
Well 15
Residual Drawdown in feet (s')
0
1
2
3
1
10
100
1000
10,000
Ratio (t/t')



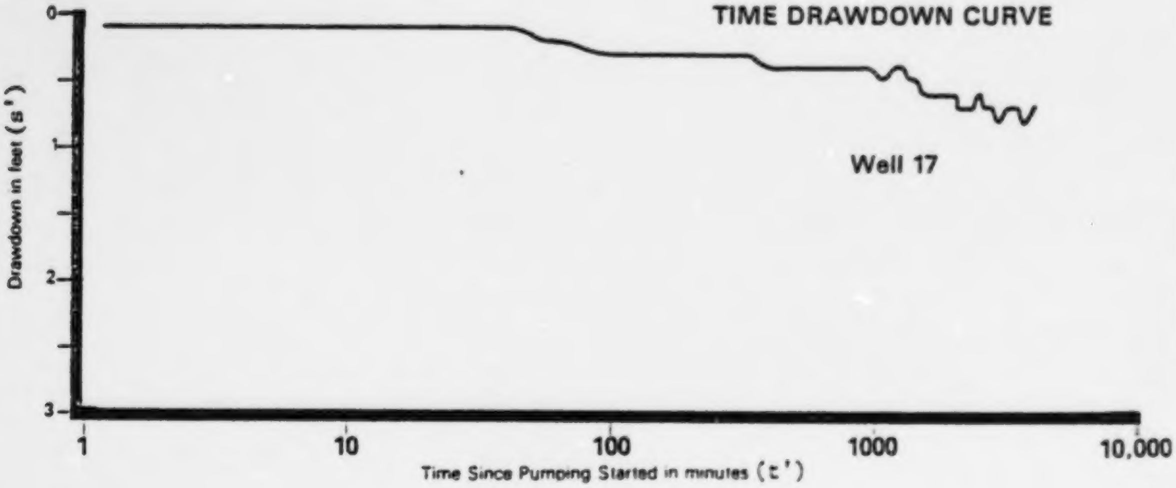
TIME DRAWDOWN CURVE

Well 16

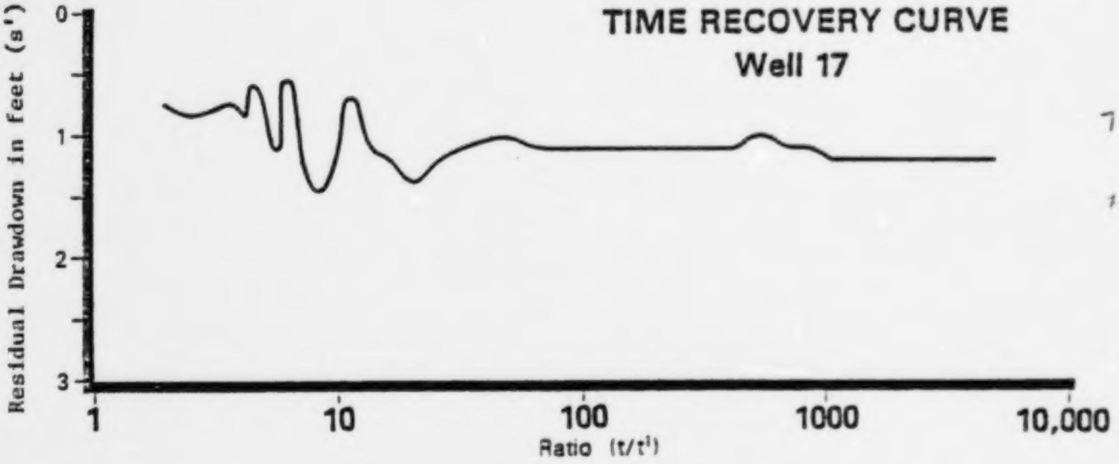


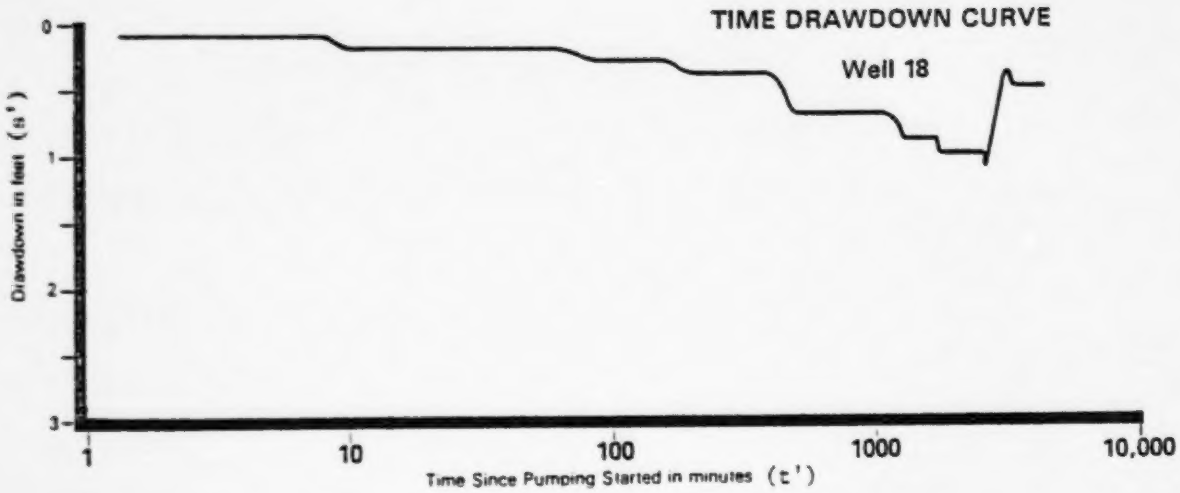
TIME RECOVERY CURVE

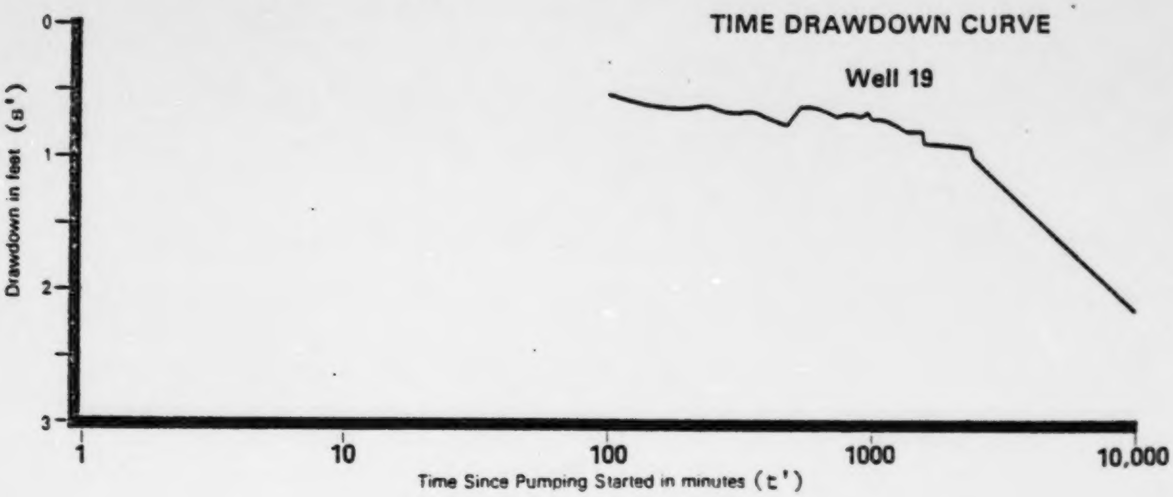
Well 16


TIME DRAWDOWN CURVE

Well 17

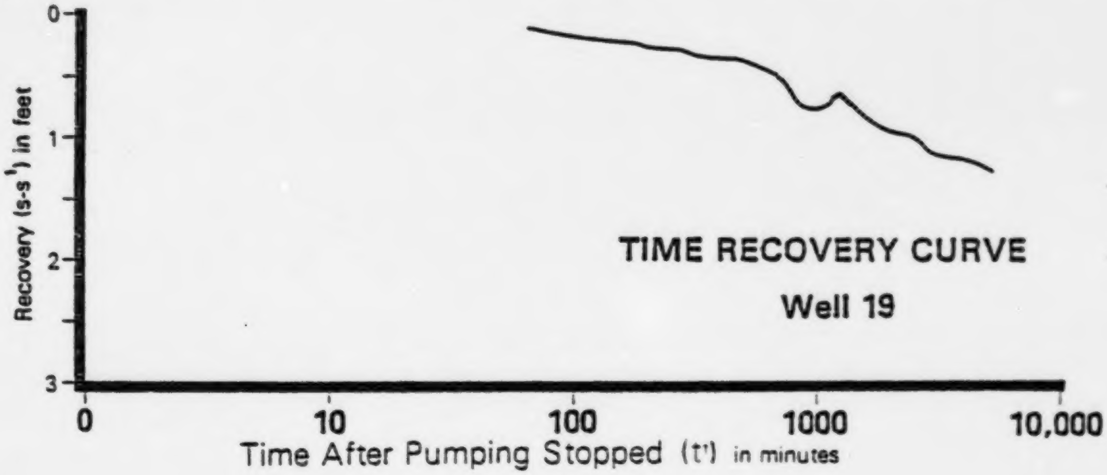

TIME RECOVERY CURVE
Well 17


TIME DRAWDOWN CURVE
Well 18
0
1
2
3
Drawdown in feet (s')
1
10
100
1000
10,000
Time Since Pumping Started in minutes (t')



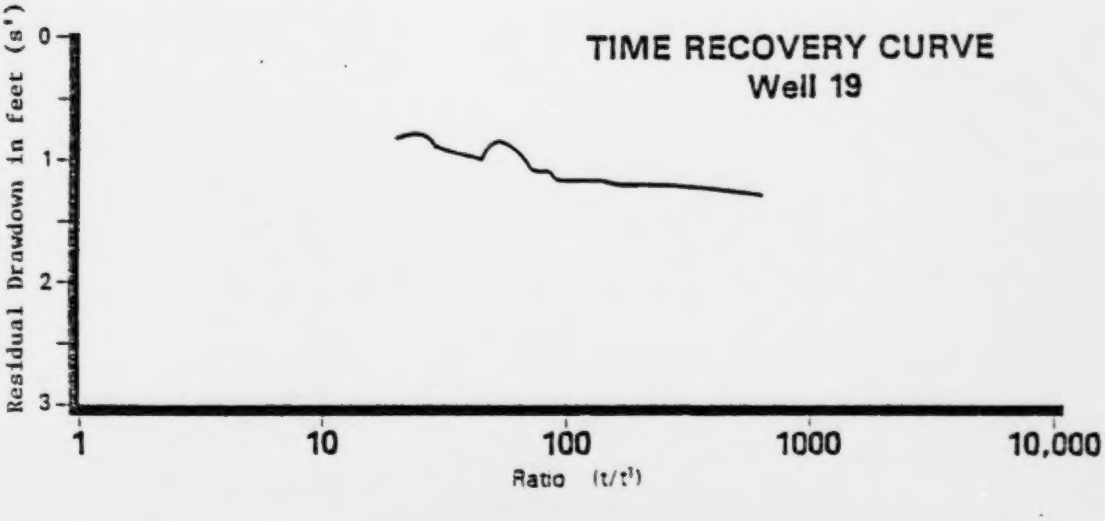
TIME DRAWDOWN CURVE

Well 19



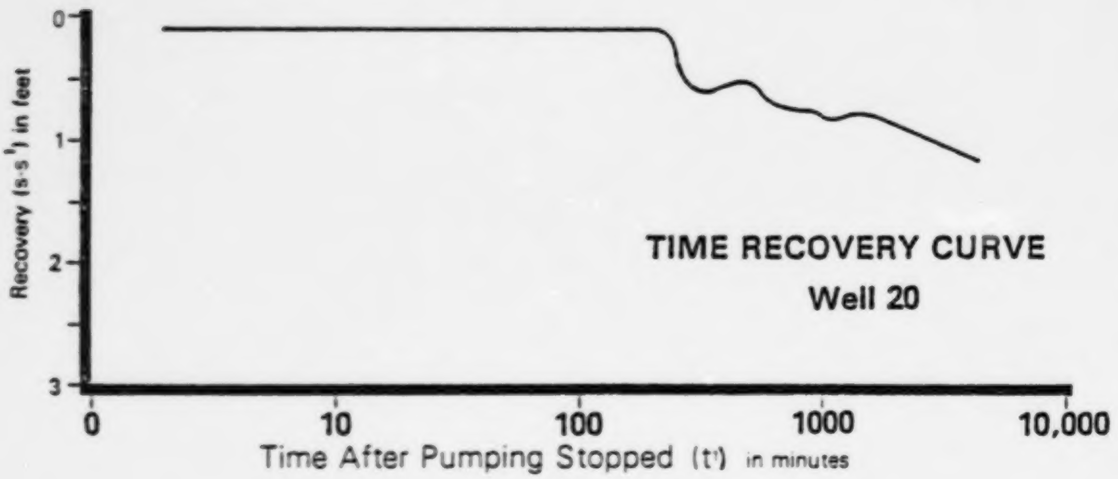
TIME RECOVERY CURVE

Well 19

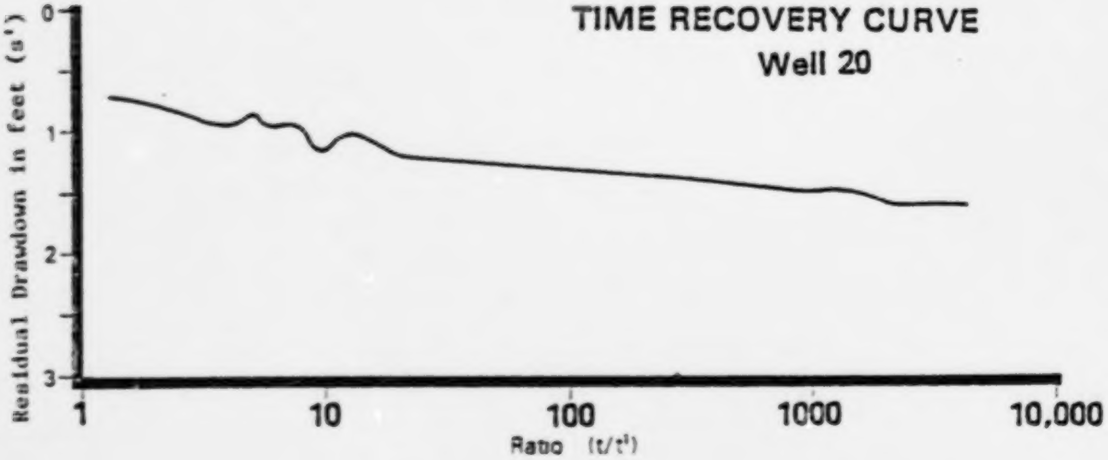


TIME RECOVERY CURVE

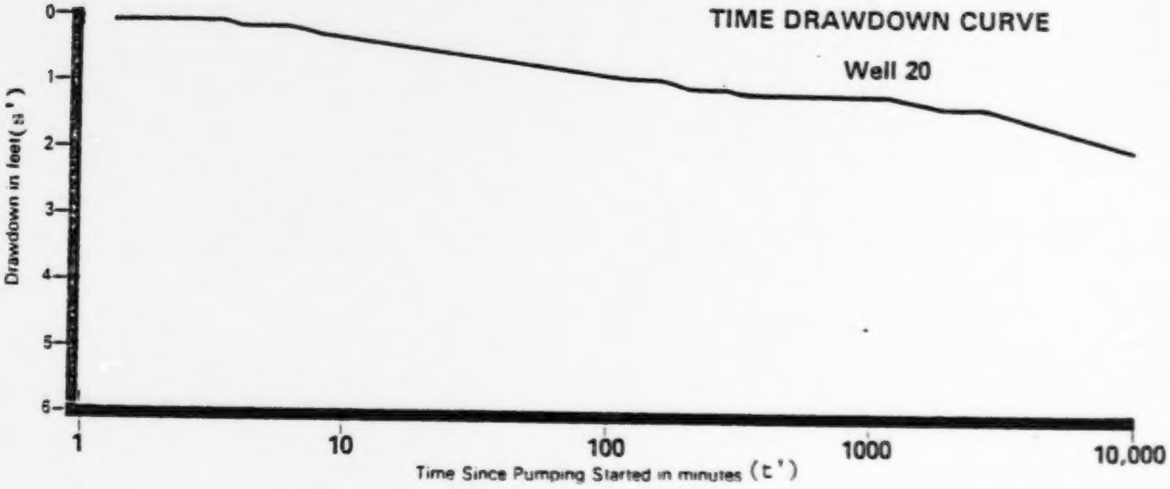
Well 19

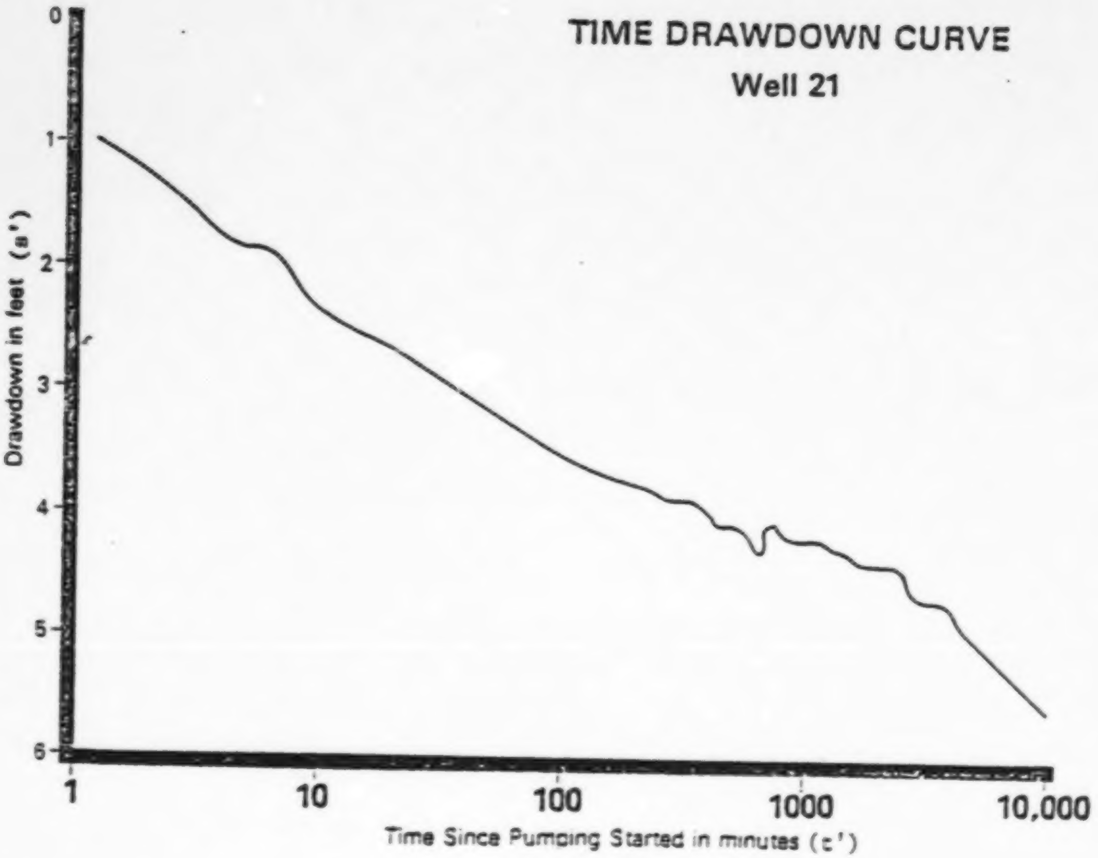


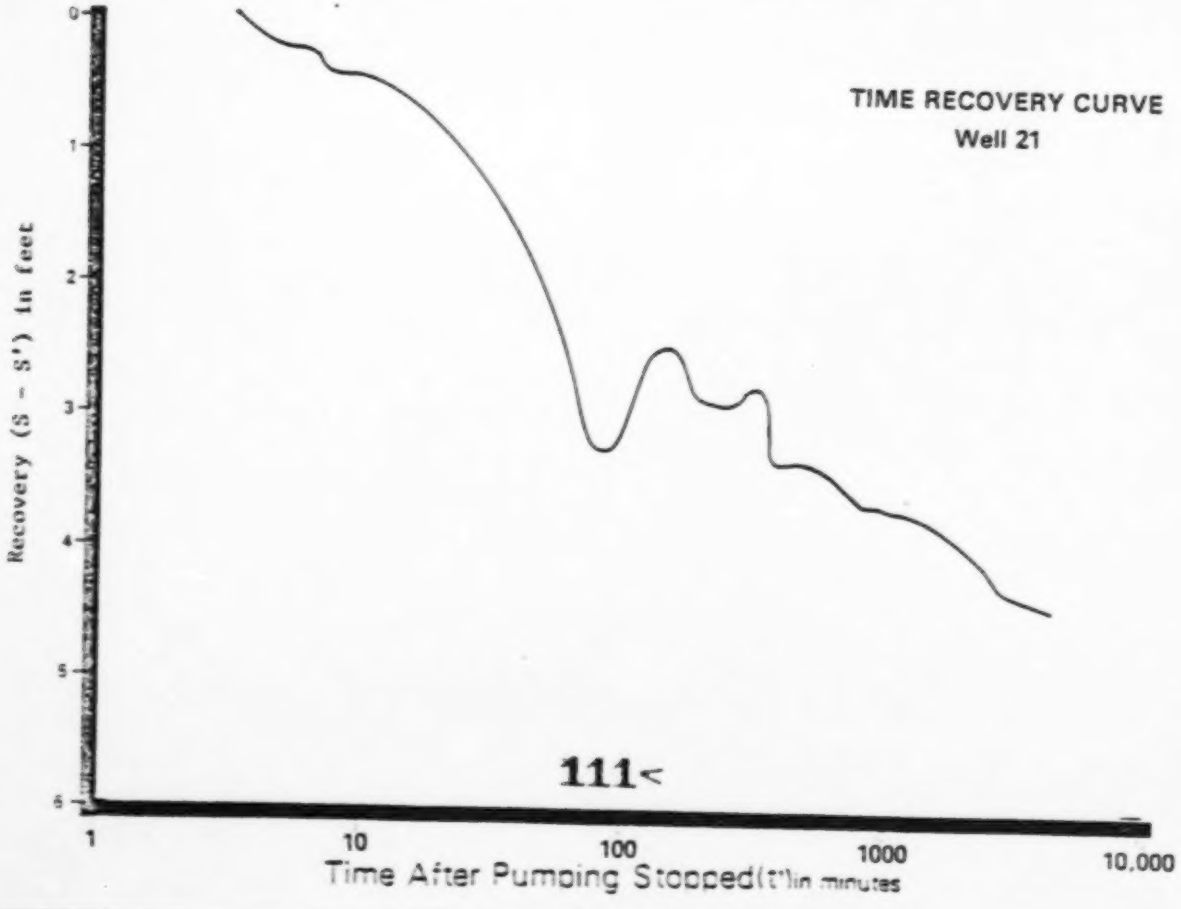
TIME RECOVERY CURVE
Well 20

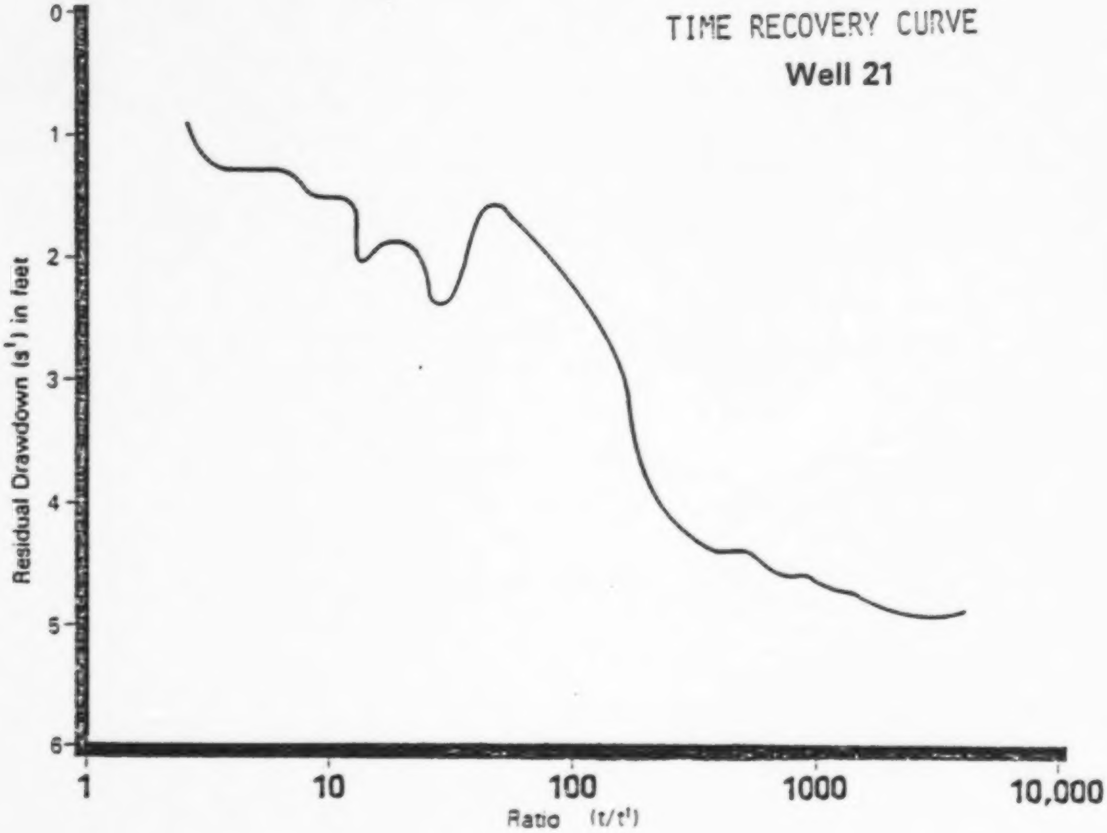


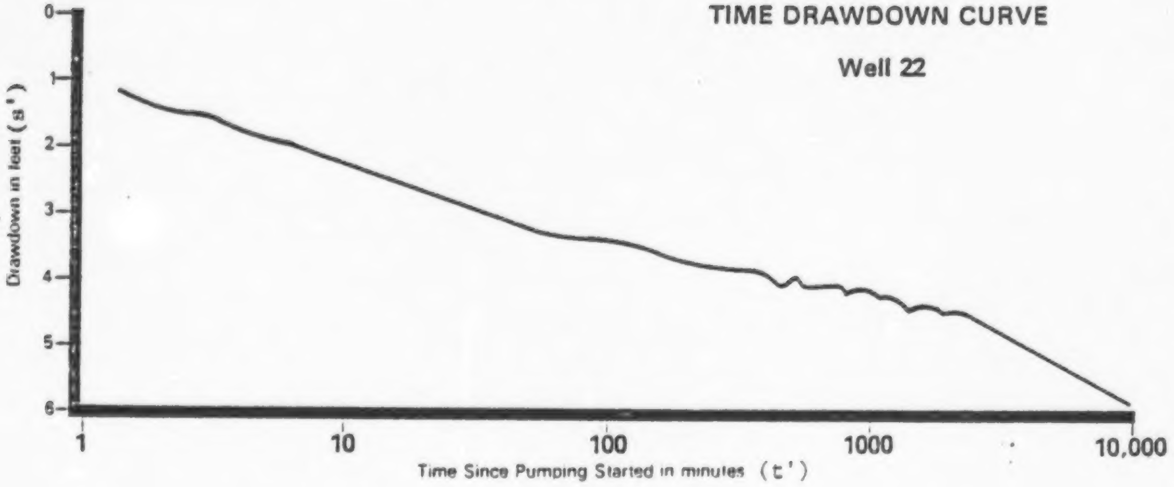
TIME RECOVERY CURVE
Well 20


TIME DRAWDOWN CURVE
Well 20
Drawdown in feet (s')
0
1
2
3
4
5
6
1
10
100
1000
10,000
Time Since Pumping Started in minutes (t')

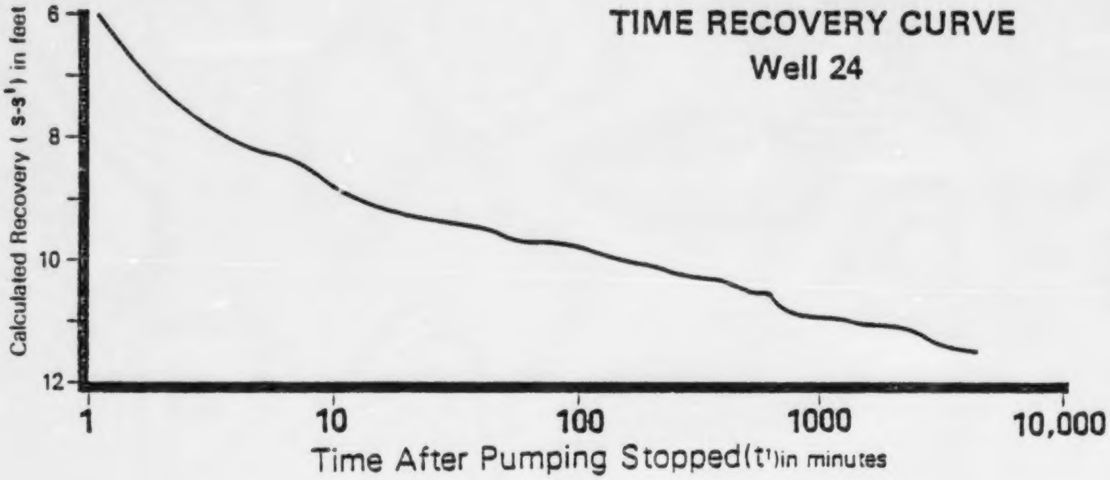

TIME DRAWDOWN CURVE
Well 21
Drawdown in feet (s')
0
1
2
3
4
5
6
1
10
100
1000
10,000
Time Since Pumping Started in minutes (t')


TIME RECOVERY CURVE
Well 21
Recovery (S - S') in feet
0
1
2
3
4
5
6
1
10
100
1000
10,000
Time After Pumping Stopped(t')in minutes

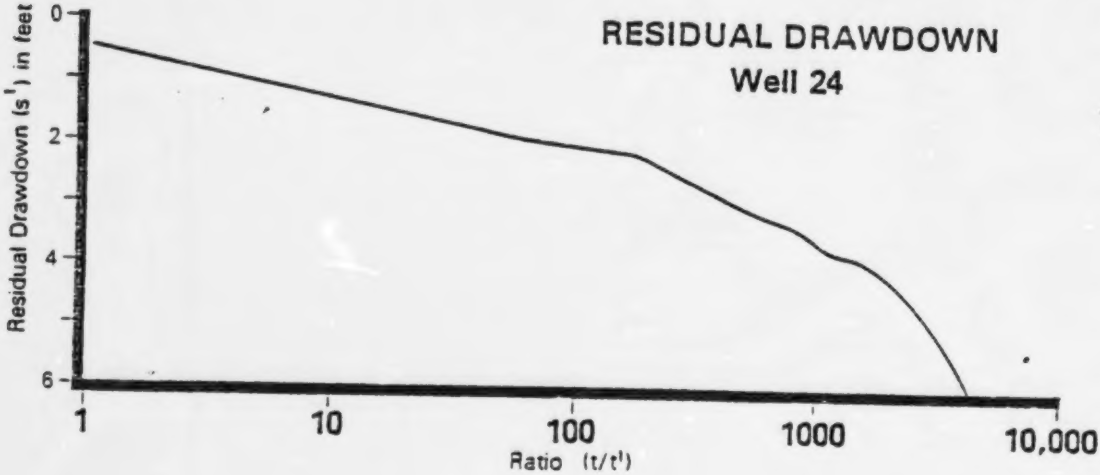

TIME RECOVERY CURVE
Well 21
Residual Drawdown (s') in feet
0
1
2
3
4
5
6
1
10
100
1000
10,000
Ratio (t/t')


TIME DRAWDOWN CURVE

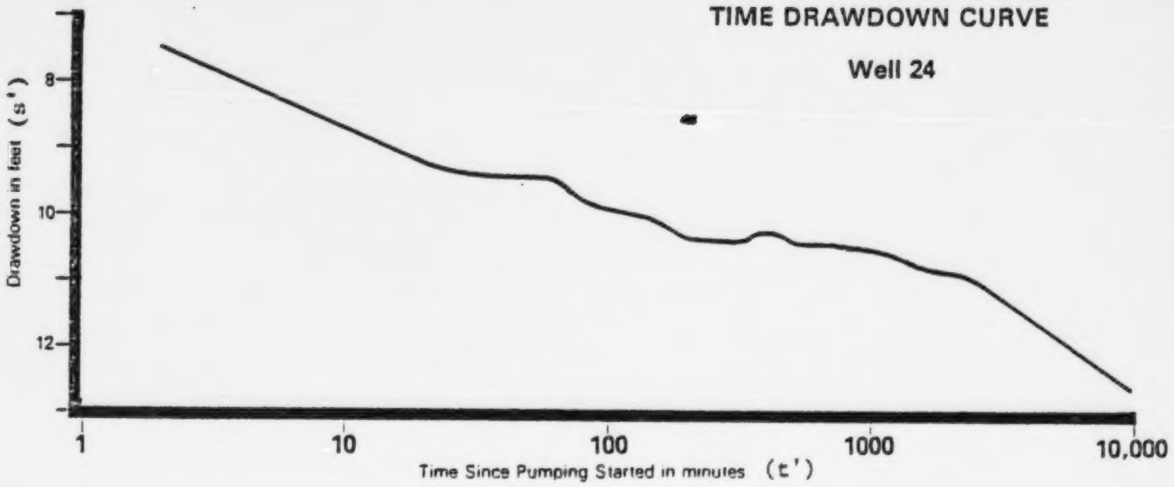
Well 22



TIME RECOVERY CURVE
Well 24



RESIDUAL DRAWDOWN
Well 24


TIME DRAWDOWN CURVE
Well 24
Drawdown in feet (s')
8
10
12
1
10
100
1000
10,000
Time Since Pumping Started in minutes (t')